SNAP

A survey network adjustment program

Version 2.15

Users Manual

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Chapter One: Introduction to SNAP

What is SNAP?

SNAP (Survey Network Adjustment Program) is a program for adjusting the coordinates of stations in a survey network to best fit the observed data. It can use horizontal angles, zenith distances, slope and horizontal distances, azimuths, projection bearings, levelled height differences, GPS data (baselines or multistation), and latitude and longitude observations.

SNAP uses as input a station coordinate file listing the stations to be used in an adjustment, and one or more data files of observations. It creates several files including a new version of the station coordinate file containing the adjusted coordinates and a listing file giving an analysis of the data and summarising the adjustment. It also produces a binary file which is used by the program SNAPPLOT to display graphically the observations, error ellipses, and other information about the adjustment.

Features of SNAP

Some features of SNAP are:

- It uses a rigorous least squares adjustment methodology
- It can perform vertical, horizontal, or three dimensional adjustments
- It can combine GPS and conventional survey data
- It performs the adjustment on the ellipsoid - data need not be reduced to a projection
- It can perform network pre-analysis as well as adjusting data
- It can work directly with New Zealand Map Grid and projection coordinates - conversions to and from latitude and longitude are performed internally.
- Data files are easy to read and are simply created with any text editor. Errors in data files formats are reported with the file name and line number, making them easy to locate.
- Observations can be rejected without removing them from the data file. Rejected observations are not used in the adjustment, but their residuals are listed in the output.
- The program provides many options for controlling how an adjustment is done and modifying the output files. These options can be set for individual jobs, or can be set up as defaults for all jobs.

What SNAP cannot do

Here are some of the limitations of SNAP.

- The units used by SNAP cannot be modified from the defaults. Distances are always in metres and angles in degrees, minutes, seconds.
- SNAP cannot adjust geoid heights or deflections of the vertical. However it can apply undulations and deflections specified in the input coordinate file.
- SNAP cannot model station dynamics or earth deformation.
- SNAP does not have any facility for doing “robust” adjustments (that is doing adjustments other than by least squares).

Related programs

There are a number of utility programs for processing SNAP data files. These include:

- SNAPPLOT: A graphical viewer for SNAP files used for displaying input data files and the results of adjustments. It can display stations, observations, error ellipses and relative error ellipses. It can create an AutoCad DXF format plot file that can be imported into many CAD and graphics programs.
- SNGEOID: This program is used to calculate geoid undulations at survey stations based on a grid of undulation values.
- SNAPCONV: Changes the coordinate system of lists of survey stations.
- Translators: Convert various input data formats into SNAP format files.

These programs are described in the SNAP utilities manual.

Chapter Two:
How to do a least squares adjustment

This chapter describes the procedure for using SNAP. You will require a basic understanding of least squares terminology and practice in order to use the program. Appendix Appendix C:, “A description of least squares adjustment”, describes the least squares method and defines some of the terminology that will be used in this manual.

Basic procedure

The procedure for using SNAP to derive coordinates from survey data involves the following steps:

- Create the input files required by SNAP
- Run SNAP
- Review the results in the listing file. If any problems are identified, correct the input files and run again.

Creating input files

SNAP requires at least three input files to run. These are:

- a coordinate file which lists all the stations that will be used in the adjustment. Each station is assigned a code which is used to identify it in the observations files. The format of the coordinate file is described in Chapter Chapter Three: , “Station coordinate files”.
- one or more observation files. Each observation file contains data, which may be of several different types (distances, horizontal angles, etc). Observation files are described in Chapter Chapter Four: , “Observation files”.
- a command files which instructs SNAP what to do. Command files are described in Chapter Chapter Five: , “Command files and Configuration files”.

One way to create these files is simply to type them in using a text editor. If a word processing program is used you must ensure that it saves just the text of the files and not any formatting or other characters.

In many cases you can generate some of the input files from other information. For example GPS data is generated in various formats by GPS processing software. Some utility programs are available for converting these formats to the SNAP input format. For more information see the SNAP Utilities manual. These translators create the vector observation file, and may also create coordinate and command files.

The program GPS2SITE can be used to create a station coordinate file from a file of GPS data. It requires you to enter the coordinates of one station, and then deduces the others from the GPS data.

As a convention it is recommended that you use the filename extension “.SNP” for command files and “.CRD” for coordinate files.

Running SNAP

To run SNAP use the command

SNAP *[options] command_file_name*

at the DOS command prompt (C:>). Replace *command_file_name* with the name of the command file you have created. SNAP will read the command file and other input files, adjust the coordinates, and produce a number of output files.

For large adjustments you may prefer to use SNAP386. This requires a 386 or better computer. It can do bigger adjustments than SNAP, and for larger jobs it also runs more quickly. In every other way it is identical to SNAP. The command to run SNAP386 is

SNAP386 *[options] command_file_name*

As SNAP (or SNAP386) runs it indicates the progress of the adjustment. Finally it shows the name of the output file, and if it encounters any errors it shows the name of the error file created.

Two options can be specified with the command:

-c *config_file*	Defines a configuration file that will be used for the adjustment. More than one configuration file can be specified (each with its own -c option)
-u *user_directory*	Defines the directory in which the users own configuration files are stored.

For more information about configuration files see “What is a configuration file” on page 5-1.

Reviewing the results

The main outputs generated by SNAP are a listing file, which describes the adjustment, and a binary file, which is used by the SNAPPLOT program. If SNAP encounters errors it will also create an error file. These files are described in more detail in Chapter Chapter Six: , “Output files”.

If your command file is called “MYJOB.SNP”, then the listing file will be “MYJOB.LST” and the binary file will be “MYJOB.BIN”. The error file, if it is created, will be “MYJOB.ERR”.

If an error file is generated you should resolve the problems it identifies and run SNAP again. For more information see “Common problems” on page 2-9.

The listing file provides a great deal of information about the adjustment. Your main purpose in viewing this file is to identify problems in the input data, such as gross observational errors, mistyped data, and misidentified stations. This is best done by reviewing the most significant residuals in the data which are listed at the end of the listing file, and by looking at the residuals of the individual observations.

If there are no obvious errors in the data then you should check the error ellipses and height errors of the calculated station coordinates to ensure that they meet the specifications of the job.

The SNAPPLOT program is useful for displaying the layout of the network and the geometry of the observations, the error ellipses and height errors of the stations, and the adjustments to station coordinates. For more information about SNAPPLOT see the SNAP utilities manual.

Adjustment strategies

The following sections provide some guidelines for adjusting survey data. These suggestions should not be followed rigorously - each adjustment you do should be interpreted individually with regard to all the information available about the data. A good understanding of least squares is the most useful asset in interpreting the results of adjustments.

General guidelines

Essentially a least squares adjustment is very simple. You create the input files, run the adjustment, and that's it! However there are several reasons that why an adjustment may require more attention than this. In particular you may want to

- identify and eliminate any gross errors in the data
- improve your estimates of the errors of the observations in order to get more realistic statistics in the output data
- fit the data into imperfect existing control

The simplest way to handle these problems is one at a time. If you are trying to identify gross errors and bad control at the same time it may be difficult to determine whether a large residual arises because of a problem in the data or in the fixed station coordinates. Similarly it is difficult to estimate the typical errors of the observations if the statistics from the adjustment are corrupted by gross errors or bad station coordinates.

Using a minimum constraints adjustment to identify gross errors

Generally the best way to start with new data is to use it in a minimum constraints adjustment. In this adjustment the fixed coordinates (constraints) are chosen so that they do not influence the observation residuals at all. In other words the residuals are due to the inherent inconsistencies of the data and not due to the station coordinates.

For a GPS adjustment this is usually quite simple - all that you need to do is fix one station. The reference frame rotation and scale should not be calculated (as one fixed station is not adequate control to do this).

It may be more complicated generating a minimum constraints adjustment with terrestrial data as the constraints required depend upon the observations available. Also the survey may include hanging lines to control stations which cannot be adjusted without fixing the station coordinates.

SNAP does have a facility for automatically doing a minimum constraints adjustment. To do this the command file should include the command

```
mode  3d  free_net_adjustment
```

However SNAP is not always able to correctly determine the constraints required.

Consider for example a two dimensional adjustment of horizontal angle data only. Intuitively you might expect to have to fix two stations to determine the position, scale, and orientation of the survey. However the size of the network can be deduced from the spherical excess in closed figures. Less obviously, the orientation and even the latitude can be determined by taking account of the effects of eccentricity on the network. In practice these parameters are very poorly determined and SNAP should supply constraints to fix them. If SNAP does attempt to determine them in a free net adjustment then it is likely that the adjustment will not converge.

One way of dealing this problem is to create an additional data file of invented observations to provide the missing constraints. In the example above this could include a latitude, longitude, azimuth, and distance observation. These additional observations should have (very nearly) zero residuals when the adjustment is done. If they do not then they are redundant and should be deleted.

Once a minimum constraints adjustment has converged you can check the residuals for gross errors in the data.

At the end of the SNAP output file is a list of the observations with the worst residuals. Observations containing gross errors are most likely to appear at the top of this list. Below is an example of the list of worst residuals. In this example two observations have already been rejected. The standardised residuals of these observations, 2397 and 862, are much greater than those of the remaining data, which are all less than 4.

```
The following table lists the 2 worst residuals of rejected data

From   To     Type     S.R.  Sig (%)       Line  File

3      245     SD*  2397.896  100.000 ???     11  mat_sd.dat

3      79      SD*  862.300  100.000 ???     12  mat_sd.dat


The following table lists the 10 worst residuals of used data

From   To     Type     S.R.  Sig (%)       Line  File

74     260     HA     3.561   99.982 ???     30  mat_ha.dat

221    79      SD     3.461   99.972 ???     18  mat_sd.dat

245    83      SD     2.491   98.866 ?       15  mat_sd.dat

239    221     SD     2.469   98.785 ?        9  mat_sd.dat

245    260     HA     2.429   98.627 ?       89  mat_ha.dat

260    74      HD     2.178   97.196 ?        6  mat_hd.dat

245    4       SD     2.157   97.035 ?       16  mat_sd.dat

79     236     SD     2.121   96.743 ?       20  mat_sd.dat

83     4       SD     2.107   96.622 ?       23  mat_sd.dat

221    236     SD     2.045   96.030 ?       19  mat_sd.dat
```

The residual listed in this section is the “standardised residual”. This is a measure of how much bigger the residual is than its statistically expected value. It takes into account the expected error of the observation and the redundancy of the network. Standardised residuals of up to about 3 are quite normal. In the example above, two observations with very large errors have been rejected. The two largest remaining standardised residuals are still over 3, and are considerably greater than the next largest residual.

If the worst few standardised residuals are significantly greater than the rest then they should be investigated. If there are many observations with large standardised residuals, but none outstanding, then this may indicate either that the errors assigned to some of the data are too low, or that the network geometry is too weak to allow the gross errors to be located.

Note that the observations with the largest residuals are not necessarily bad. In a survey of 100 observations you would expect 5% of the observations to be significant at the 95% confidence level. These observations still contain important information for the adjustment.

As a general policy it is better to use observations unless there is good reason to believe they are wrong. Examples of good reasons would be difficulty identifying a target for an angle observation, or poor return signal strength for a distance measurement. Unfortunately there may be gross errors in the data for which no explanation is available.

Bad observations should be rejected, not removed from the adjustment.(see “Specifying stations to adjust”, page 5-6, for a description of how to reject observations). A rejected observation is still listed in the output file, and will have residuals calculated for it. If you subsequently change the weighting of observations or reject additional observations, it is possible that an observation that appeared to be in error initially will no longer be inconsistent with the remaining data.

It is sensible to reject only the worst one or two observations at a time. Although many observations may have large residuals this is often because the least squares adjustment has distributed the gross error in one observation into neighbouring observations. When the incorrect observation is rejected the other observations may be able to form a consistent adjustment with no unduly large residuals.

If several observations have the same standardised residual then they should be all accepted or all rejected. If you reject one and accept another then you may be biasing the solution.

You should always check the residuals of observations that have been rejected after you have done an adjustment in case any rejected observations no longer have large residuals and can be brought back into the adjustment.

You may not be able to identify all gross errors in a survey using a minimum constraints adjustment. Observations with little or no redundancy, such as hanging lines, may still have undetected gross errors. SNAP identifies these line by an "@" in the listing. These lines can only be checked by adding additional information to the adjustment, either by making additional observations, or by including fixed station coordinates which are known to be correct.

Improving estimates of observation errors

To do a least squares adjustment we need to provide expected errors for the observations. These will generally be based either on our experience with the equipment and observation techniques, or on manufacturers specifications. For GPS data they may also be determined by the GPS software.

The SNAP listing includes an error summary which by default provides statistics for each data type and each data file in the adjustment. Here is an example of the statistics for each data type:

```
Summary of residuals classified by data type

Classification                              Used        Unused       Total
                                           RMS  Count   RMS  Count   RMS  Count

slope distance                             1.83   15 1801.87    2  618.04   17

horizontal angle                           0.85   60     -      -    0.85   60
```

This listing may be used to revise the expected errors of the observations.

You should first ensure that there are no gross errors used in the adjustment. The listing should be obtained minimum constraints adjustment (as described above) to ensure that the observations are not being influenced by incorrect fixed stations coordinates.

In the example above the root mean square error (RMS) of slope distance residuals is 1.83 compared with 0.85 for horizontal angles. Both these values are based upon a reasonable number of observations (in the "Count" column), and so are reliable statistics. This suggests that the expected errors of slope distances should be multiplied by 1.83, and the expected errors of angles should be multiplied by 0.85. You can do this either by modifying the data file, or by including the following lines in the command file:

```
classification   data_type   SD   error_factor  1.83
classification   data_type   HA   error_factor  0.85
```

SNAP allows you to further classify the observations in any way that you want. For example, if you have several different EDM's in a survey you may want to estimate different errors for each meter. In the data files you can define a classification called EQUIPMENT, and specify "EQUIPMENT" for each observation (see "Classifying observations", page 4-13, for more detail on how to do this). SNAP is then able to generate an error summary for each equipment by adding the command

```
summarize_errors_by data_type equipment
```

to the configuration file.

Avoid using statistics based upon only a few observations - you cannot reliably update expected errors using statistics based on only a few observations. As a rough guide you should have at least 20 degrees of freedom in the adjustment, and at least 10 observations for each data type for which you are going to change the expected error.

Fitting observations into existing control

Often a survey must fit into an existing control network. In SNAP this is done by "fixing" the coordinates (horizontal, vertical, or both) of the control stations. These coordinates are constrained to not alter in the adjustment.

If there are sufficient data and redundancy in the network then you should attempt to identify gross errors and assess the observation errors using a minimum constraints adjustment before fitting into the control network (as described above).

An adjustment with fixed control stations may have significant residuals for a number of reasons:

- the data contain undetected gross errors in observations with low redundancy in the minimum constraints adjustment
- the coordinates in the station file are wrong or the stations are incorrectly identified (for example by confusing eccentric stations)
- the control network is not as accurate as the survey that it is fitted to
- there are datum differences between the control network and the survey (this applies mainly for GPS surveys, see below)

The first two cases - gross errors in observations or incorrect station coordinates - cannot be separated if the observations have little or no redundancy. Both the observation and the control must be reviewed critically. If there is not obvious error in either, then the observation should be rejected. The control station will then have no affect on the adjustment.

If the control network causes large residuals in observations which have been checked by a minimum constraints adjustment then the station coordinates may be in error. Obviously the first step is to check that the coordinates are entered correctly into the coordinate file and the stations are correctly identified.

It is often the case that the control network is not as accurate as the survey that is fitted to it. The control coordinates may be based upon old observations with less accurate equipment. SNAP provides some options for resolving the difference between the control and the survey. It can calculate an overall scale difference by adding to the command file:

```
reference_frame_scale_error calculate
```

You can also handle differences in orientation for azimuth and projection bearing data by assigning a bearing orientation error to the data. To do this put the line

```
#bearing_orientation_error DEFAULT
```

before any observations in the data files, and add the line

```
bearing_orientation_error DEFAULT calculate
```

to the command file.

For GPS data rotations and scale difference are handled by the GPS reference frame. This is discussed below.

If these options cannot resolve the differences between the survey and the control then you can try floating the stations rather than fixing them. When the stations are floated their original coordinates are treated as observations rather than as constraints. By reviewing the "floated stations" section of the output file you can see whether there are discrepancies in just on or two stations, or whether the lack of fit with the control is more pervasive.

Ultimately you will have to accept some degree of incompatibility between the control and the survey data. There are several ways that you can deal with this:

- fix the control stations and accept the distortion that this introduces in the new survey. This may be adequate if the survey and control fit together reasonably well.
- float the control stations using sensible values for the horizontal and vertical errors. This will introduce less distortion into the network. Also the error ellipses of the adjusted stations will be more realistic, since they will indicate how the error in the control stations is propagated into the network.
- model the distortion between the control and a minimum constraints adjustment, and apply this distortion to the coordinates from the minimum constraints adjustment. This will require a separate program, but is a more realistic approach.

One concern with fixing or floating the control stations is that the distortion in the adjusted coordinates depends upon the geometry of the network, which is nothing to do with the errors in the control.

Adjusting GPS surveys

GPS baselines are usually expressed as vector components in the WGS84 reference frame. However the coordinates of the fixed stations in an adjustment are often expressed in a different reference frame for which the X, Y, and Z axes are not exactly parallel to the WGS84 axes. The observed vectors must be converted to the reference frame of the fixed stations before they can be used in an adjustment.

In New Zealand, for example, survey stations are usually referenced to the NZGD49 datum, which is defined in terms of the horizontal coordinates of the stations in the 1949 adjustment. The vertical reference in New Zealand is defined by levelling from a number of tide gauges. At any location the difference between WGS84 and the NZGD49 reference frames can be approximated by a scale, a rotation, and a translation. This difference varies across the country, as the NZGD49 datum is not internally consistent to the accuracy of current survey equipment.

The reference frames may also appear to differ if geoid heights are not available for the stations. In this case the station elevations in the coordinate file are orthometric heights measured above the geoid (sea level), whereas GPS vectors are in terms of ellipsoidal heights and take no account of the height of the geoid. The geoid can be modelled locally by a sloping surface relative to the ellipsoid. When geoid heights are not available to SNAP the effect is as if the geoid were removed. To use GPS vectors in the adjustment, the vectors must have the geoid heights removed from them also. Locally this can be approximated by rotating the vector to remove the slope of the geoid surface. Because the geoid heights are unknown, the rotation is also unknown and must be calculated as part of the adjustment

In SNAP each GPS observation has an associated reference frame code. By default this is "GPS" for all observations. Each code defines a reference frame which may differ from the coordinate file frame by a scale and rotation.

The reference frame scale and rotation can be calculated by including the command

```
reference_frame GPS calculate scale rotation
```

in the command file.

In order to be able to calculate the reference frame rotations and scales you need at least two horizontally fixed stations and three vertically fixed stations. The vertically fixed stations will ideally span the extents of the network. They should not lie in, or near to, a straight line.

Note that in a minimum constraints adjustment of GPS data only it is simplest to not calculate the reference frame parameters and just fix one station. However if the survey includes conventional observations then the reference frame parameters should be calculated.

You should always do three dimensional adjustments of GPS data. In a survey of mixed GPS and conventional data there may be some stations which cannot be fixed in three dimensions. These should be fixed or floated. For example a station which is fixed by horizontal angles only can be fixed or floated vertically.

Handling eccentric stations

SNAP does not have any facilities for handling observations from eccentric stations. These can be dealt with in two ways:

- add the eccentric stations and the observations defining their eccentricity to the adjustment
- reduce the observations to the central station

Adding eccentric stations to the adjustment is the more rigorous approach as the errors in defining the eccentricity are properly accounted for. If the observations are reduced to the central station before being used in SNAP then the observations defining the eccentricity are being treated as error free.

Occasionally this approach may give rise to problems in the adjustment where eccentric stations are very close to the central station. You should ensure that errors of the observations defining the eccentricity are defined sensibly. For example, an eccentric station 1/Ecc may be defined as being 5 metres from station 1 and on line to station 2. The alignment must be entered into SNAP as a horizontal angle observation at station 1. If the alignment has been observed to a better accuracy than 0.5 mm, the error of the angle is 0.5mm in 5 metres, or about 20 seconds of arc.

If eccentric stations are being calculated in the adjustment then you also need to calculate reasonable trial coordinates for the stations. These should not be the same as the coordinates of the central station, and should be in approximately the correct direction from the central station.

In large adjustments with many eccentric stations it may be preferable to reduce the observations. This avoids significantly increasing the number of stations the adjustment, and avoids the need to calculate initial coordinates for those stations.

Using SNAP for network preanalysis

SNAP has a preanalysis mode which can be used to assist designing survey networks. The procedure for preanalysis is much the same as that for normal adjustments except that the data is invented rather than observed. Generally you do not need to use sensible values for observations - you can just put 0 for all values. The only exception is that for distance and GPS data the observed values are used to calculate part per million errors for the observations. To ensure that appropriate values are used you can either enter suitable distances and vector differences in the data file, or avoid using part per million errors.

For GPS data you can use the utility program SITE2GPS to create trial GPS baselines or multistation data files from the station coordinates.

For network analysis you should modify the residual listing to display the redundancy factor of the observations. This provides an indication of how useful the data are in the adjustment, and how well they are checked. The redundancy factor is a number between 0 and 1. Values near 0 indicate observations that are very poorly checked, where there is insufficient redundancy. Values near 1 indicate observations which are almost completely redundant, and could be removed from the observation scheme without weakening the network.

SNAPPLOT is useful for reviewing the results of the preanalysis. You can use it to view station error ellipses, relative error ellipses and errors in heights and relative heights. You can also view the redundancy factor (highlighting observations according to the value of the redundancy factor).

Using SNAP for vertical adjustments

SNAP can be used to do vertical adjustments only. However if the adjustment includes zenith distance data you will require accurate horizontal positions for the stations. This is because the height difference derived from zenith distance data depends upon the distance between the stations, which in turn depends upon their coordinates.

If you do not have accurate locations you can do a 3d adjustment and "float" stations horizontally. By doing this the uncertainty in their positions is reflected in the derived elevations. Note that doing this will affect that statistics, as the trial horizontal positions of the stations are treated as observations.

Common problems

If SNAP encounters problems when it is running it will create an error file. The errors that you are most likely to encounter are:

- there are format errors in the input files
- a singularity occurred in the adjustment
- the adjustment failed to converge
- there is not enough memory to run the program.

These are described in the following sections.

Format errors in the input files.

If SNAP has problems reading the input files then the error file will briefly describe the problem, and will specify the name of the file and the line number at which the error occurred. For errors in data files see “Troubleshooting data file errors” (page 4-18).

A singularity occurred in the adjustment.

If the adjustment is not well defined, for example if no station has been held fixed, then the error file will state that a singularity has been encountered. A singularity can also occur if there is a hanging line which does not have a distance and angle measurement (and vertical measurement in a 3d adjustment), or if there is any other configuration defect in the network. Look at the listing file for more information about the singularity. It will indicate at which station or parameter the singularity was detected.

Failure to converge.

The least squares adjustment may not reach a solution if the initial coordinates supplied for the stations are very inaccurate, if the data contain very large errors, or if the station codes for the data are incorrect.

When this occurs it is often helpful to run the program in “data_check” mode to see how well the observations fit the initial station coordinates. This may identify unusually bad observations or initial station coordinates.

If this does not highlight the problem stop the adjustment after one iteration and check whether any stations are moving excessive distances. This is done by including the command “max_iterations 1” in the command file. It may be helpful to display the station adjustments with SNAPPLOT. Stations with excessive adjustments may indicate defects in the network geometry or insufficient constraints on the adjustment.

In some cases where the adjustment is weakly constrained it may converge, but only very slowly. In this case the program may terminate because the maximum number of iterations has been exceeded. You can avoid this by increasing the maximum number of iterations in the command file.

There is not enough memory for the program.

The number of parameters (mainly station coordinates) that can be adjusted depends upon the memory available in the computer and the configuration of the network. If you are using a 386 computer or better then choosing SNAP386 instead of SNAP will allow you to adjust larger networks.

Chapter Three: Station coordinate files

What is a station coordinate file

A station coordinate file is a data file containing a list of all the survey stations to be used in an adjustment. Each station is denoted by a code, and has a position. A station may also have a short text description, and a geoid undulation and separation of the vertical. The file also defines the coordinate system to which the station positions are referenced.

The station positions may only be approximate of course, since SNAP will calculate improved coordinates using the survey observations. One of the outputs of SNAP is a revised coordinate file containing the adjusted coordinates.

Each station in an adjustment must have a unique station code. This is used to identify the station in other data files. The code can be up to ten characters long, and can contain numbers, letters, and other characters. Codes cannot contain blank characters. and should not contain exclamation marks or hyphens. It is recommended that only numbers, letters, and the underscore '_' are used in codes. It is recommended that station codes be no more than 5 characters long, as this ensures that the SNAP output file is no more than 80 characters wide (which makes it easier to view and print).

Station coordinate files can be generated from GPS baseline data using the program GPS2SITE.

The station coordinate file may be modified by SNAPCONV (which changes the coordinate system) and SNGEOID (which adds or removes geoid information).

Format of the station coordinate file

A station coordinate file contains two or three lines of header information followed by a list of stations, one per line. The file may also contain blank lines and comments which are ignored. Any line starting with the exclamation mark (!) is treated as a comment.

The file header

The station file header contains two or three lines, which define the network name, the coordinate system, and the format of the station coordinates (specifically, whether the coordinates include information about the geoid).

The first line of the file should be a description of the network or of the job. It is ignored in the adjustment. This line cannot be blank

The second line of the header specifies the coordinate system. The coordinate system is defined by a code such as "NZMG" or "WGS84". This code refers to a coordinate system defined in the coordinate system definition file (COORDSYS.DEF) installed with the program (see Appendix Appendix A:, "Coordinate system definition"). The second line of the header should contain just this code.

The third line of the header is optional - it is only present if the station file does not contain geoid undulations and deflections of the vertical. In this case the third line should be “no_geoid”. By default the station elevations in the file are treated as orthometric heights. You can add the text “ellipsoidal_heights” after “no_geoid” to instruct SNAP to treat the heights as ellipsoidal heights. This makes no difference to SNAP - missing geoid undulations are treated as zero so that ellipsoidal heights are the same as orthometric heights. It does affect the SNGEOID and SNAPCONV programs.

Station data

After the header lines each station is specified on a separate line. The format for the station coordinates depends upon whether the coordinate system is an ellipsoid or a projection. The layout is

code position [geoid data] [name]

code is the code of the station. Every station in the file must have a unique code. The code is used to reference stations in data files.

position defines the position of the station. The format depends upon the type of coordinate system used. This may be a projection system, a geodetic system, or a geocentric (XYZ) system. (Geocentric systems are not well supported by SNAP - in the output listing they are converted to a geodetic system).

For projection coordinate systems the position is specified by an easting, a northing, and a height. All are in metres. The height is treated as an orthometric height unless the header specifies ellipsoidal heights. Here is an example of a projection position.

```
2538291.085  6771032.082  135.20
```

For geodetic coordinate systems the position is specified by the latitude, longitude, and height. Latitude and longitude are in degrees, minutes, and seconds followed by the hemisphere. The height is in metres - it is orthometric unless the header specifies ellipsoidal heights. Here is an example of a geodetic position

```
41 08 21.12734 S 170 23 17.55275 E 135.20
```

For geocentric coordinate systems the position is defined by the X, Y, and Z coordinates. For example

```
-4747566.374    837115.029  -4162353.283
```

geoid data is only present if the header does not include the line “no_geoid”. If geoid information is present (ie if the third line of the header is omitted), then the geoid data should define the deflection of the vertical north and east (in seconds), and the geoid undulation (the height of the geoid above the ellipsoid in metres). An example of geoid information is

```
-5.0 3.0 25.23
```

The name of the station is optional: if none is specified then the code is used for a name.

Example of a station coordinate file with geodetic coordinates

The following example shows the beginning of a station coordinate file containing coordinates in a geodetic (latitude and longitude) coordinate system, in this case NZGD49. The file lists the deflections and geoid undulation of each station. The data do not need to be aligned in columns, though the file is more readable if they are. The comment line start “!Code” is not required.

```
Mataura 3rd Order Control
NZGD49

!Code  Latitude           Longitude         Height   Xi  Eta  Geoid  Name
3   46 08 20.525000 S 168 52 00.279000 E  480.270  0.0 0.0  6.356  L Waimumu Hd
4   46 11 28.068000 S 168 47 48.332000 E  150.570  0.0 0.0  6.328  R Lindhurst Hd
74  46 09 34.880000 S 168 50 16.999000 E  146.900  0.0 0.0  6.339  Q Waimumu Hd
79  46 11 39.771000 S 168 52 40.207000 E  110.300  0.0 0.0  6.373  I Tuturau SD
83  46 12 19.375000 S 168 51 08.065000 E   51.130  0.0 0.0  6.362  N Lindhurst Hd
221 46 13 38.262000 S 168 53 17.920000 E  309.810  0.0 0.0  6.382  Mataura No2
```

Example of a station coordinate file with projection coordinates

The following example shows a station coordinate file containing projection coordinates. The projection is defined by the code “BLUF” on the second line. This is defined in the COORDSYS.DEF file as a Transverse Mercator projection based upon NZGD49. In this case the deflections and undulation are not included. This is signified by the third line “no_geoid”.

```
Mataura 3rd Order Control
BLUF
no_geoid

3    340483.70  751109.23  480.27   L Waimumu Hd
4    335042.67  745351.66  150.57   R Lindhurst Hd
74   338252.52  748827.58  146.90   Q Waimumu Hd
79   341299.31  744951.34  110.30   I Tuturau SD
83   339315.64  743741.47   51.13   N Lindhurst Hd
221  342082.84  741287.14  309.81   Mataura No2
```

Chapter Four: Observation files

About observations

SNAP handles most data types used in surveying. Generally SNAP uses the data as it is measured (the exceptions are projection bearings and sea level distances). The input data should not be reduced to a projection. Only environmental corrections (such as atmospheric temperature corrections to distance data) should be applied. For GPS data the GPS reduction should be done to derive baseline or multistation vectors.

Observations are entered as measured from an instrument to a target. The instrument and target are assumed to be located at a specified height above their survey stations. SNAP has no facility for handling eccentric observations. To use eccentric data you must either correct the data for the eccentricity or treat the eccentric location as a survey station distinct from the central station.

SNAP can read observations from more than one data files. Each file can contain data of several different types.

SNAP uses units of metres for all distances, and degrees, minutes, and seconds for all angles. Angle errors and residuals and reference frame rotations are expressed in seconds. Scale errors are measured in parts per million (ppm).

Observation types

Distance data

SNAP supports three types of distance measurement. These are:

- slope distances: the measured distances between an instrument and target.
- horizontal distances: the distance between points at the same horizontal location as the instrument and target, but at the mean elevation of the instrument and target.
- ellipsoidal distances: the arc distance between the instrument and targets reduced to sea level.

The data file should contain the distance in metres. For all types the distance should be corrected for atmospheric effects.

The data file also specifies the error associated with the distance. This is expressed as a millimetre and a part per million component. The two components of the error are treated as being independent. That is, the total error of the distance is calculated as the square root of the sum of the squares of the millimetre and part per million components. For example, on a 3km line with a 4mm ± 1ppm error the error of an observations is $\sqrt{((4\text{mm})^2 + (3\text{km} \times 1.10^{-6})^2)} = 5\text{mm}$.

Distances can have an associated distance scale error. This is a code which references a scale error. For example the code could be the name of the instrument. In SNAP you can specify a scale error to apply for each code. You can also instruct SNAP to calculate a scale error corresponding to the code.

Distances in SNAP are also influenced by the reference frame scale error. This is an error in the local scale of the reference frame (i.e. the fixed stations used to constrain the adjustment).

The SNAP output listing includes the distance and its residual in metres by default. It can also show the residual expressed in parts per million.

Distance ratio data

Distance ratios (or line ratios) are a set of distances observed from a single station which are assumed to have a common scale error. This assumption may be supported by using an appropriate observation scheme, such as observing rounds of distances.

Distance ratios are entered into SNAP as the measured slope distances in metres. They should not be reduced by (for example) dividing by one of the distances to obtain literal ratios. Atmospheric corrections should be applied if their proportional affect is not the same for all lines (for example if reflector station temperature and pressure are measured and used).

In SNAP you can choose to treat distance ratios as either a set of ratios (that is, with a common scale error), or as a set of uncorrelated slope distance observations by changing the command file. The data file does not need to be modified.

As for distances, distance scale errors and the reference frame scale error can apply to distance ratio data. However they will only affect the result if the observations are treated as uncorrelated distances. Otherwise they will be incorporated into the scale factor applying for the set of ratios.

The SNAP output listing expresses the distances and their residuals in metres by default. It can also include the residuals expressed in parts per million. If observations are treated as distance ratios then SNAP will also output the scale error for each set of distance ratios.

Horizontal angle data

Horizontal angles are entered as a set of directions observed from one station to a number of other stations.

The angles are expressed in degrees, minutes, and seconds. SNAP supports two formats for angle data

- as three numbers (e.g. 123 45 06.7)
- as a single number following the convention adopted by HP calculators (e.g. 123.45067).

The format used is specified in the data file.

The errors of angles are expressed in seconds.

In the SNAP output listing the residual are expressed in seconds. You may also show the residual as a distance. This is the minimum distance that the target would have to be moved to make the observed direction exactly correct.

Azimuth data

Azimuth data are observed bearings from the instrument station to a target station. These are expressed as an angle measured from north through east. These are assumed to be referenced to true north as defined by the datum of the station file coordinate system.

Azimuth measurements are often done by observing celestial objects. They may be significantly influenced by the deflection of the vertical. SNAP assumes that the data have already been corrected for the deflection. (This is because to apply a correction it is necessary to know the position of the celestial object - this information is not supplied to SNAP.)

Azimuths may be subject to an associated “bearing orientation error”. This is a constant angular offset (measured in seconds) which may be applied to, or calculated for, a group of azimuth observations. This is intended for handling bearings on a survey plan (this is not rigorously correct, since the bearings on a survey plan are projection bearings, not geodetic azimuths).

The azimuths are formatted in the same way as other angles, either as degrees, minutes, and seconds, or in the HP format.

Errors and residuals of azimuths are expressed in seconds of arc.

Projection bearing data

Projection bearings are bearings as calculated between the coordinates of the instrument and target station in a projection. These are not true observations. Usually the only time projection bearings will be used is for reprocessing data recorded on survey plans.

The data file must specify the coordinate system in which the projection is defined. This is defined by one of codes in the coordinate system definition file. The projection coordinate system must be able to be converted to the station file coordinate system, and it must define a projection. That is it must define projection east and north coordinates. It cannot be a coordinate system such as NZGD2000, which is defined in terms of latitude and longitude.

Like azimuths, projection bearings may be subject to a bearing orientation error.

The format of projection bearings is identical to that for azimuths.

Zenith distance data (vertical angles)

Zenith distance data should be entered without refraction and curvature corrections applied (these corrections are done by SNAP). SNAP can be used to calculate one or more refraction coefficients to best fit the data.

Zenith distances are expressed in the observation file as degrees, minutes, and seconds in exactly the same way as horizontal angles.

Height difference data

Height difference data represent the difference in orthometric height between two stations.

Height differences are expressed in metres. Errors of height differences are expressed in millimetres.

Latitude and longitude data

Latitude and longitude data represent the observations of the latitude or longitude of a survey station.

The observations are expressed in degrees, minutes, and seconds, followed by a hemisphere (“E” or “W” for longitude, “N” or “S” for latitude). As for horizontal angle data the angle can be expressed as degrees, minutes, and seconds, or using the HP calculator format.

The latitudes and longitudes are assumed to be ellipsoidal rather then astronomical values. They are not influenced by the deflection of the vertical.

Errors and residuals of latitude and longitude observations are expressed in seconds.

GPS baseline and multistation data

GPS data are represented as vector differences between two GPS receivers. The vector is typically expressed as X, Y, and Z components in a geocentric reference frame (e.g. WGS84).

SNAP can handle baseline vectors, which are simple vectors between two stations, and multistation data, which are a correlated group of vectors observed and processed simultaneously.

All GPS observations are corrected for differences between the GPS and the coordinate file reference frames. The difference is modelled by a rotation and a scale difference.

SNAP can use more than one GPS reference frame - each frame is identified by a short code. By default the reference frame code for all observations is "GPS". SNAP can calculate a rotation and scale for each reference frame.

GPS data in SNAP is also influenced by the reference frame scale error, which is a scale error associated with the reference frame implied by the fixed station coordinates.

The errors of GPS vectors can be expressed in several ways:

- a full covariance matrix of the X, Y, and Z vector components
- the standard errors of the X, Y, and Z vector components and their correlation matrix
- the standard errors of the East, North, and Up components. The correlation between the components is assumed to be zero

All errors are expressed in metres (and covariances in m^2). See "GPS error formats", page 4-14, for more details.

In the listing file the residuals are expressed as components in the east, north, and up directions.

Additional parameters of observations

GPS reference frames

In SNAP each GPS observation has an associated reference frame code (see "Adjusting GPS surveys", page 2-7, for a discussion of GPS reference frames). By default this is "GPS" for all observations. Each code defines a reference frame which differs from the base frame by a scale and rotation. You either specify the rotations and scales for each reference frame, or you can instruct SNAP to calculate values for some or all of these components.

The rotation is expressed in terms of components of rotation about three axes. These can be either the XYZ axes of the fixed station reference frame, or topocentric axes (east, north, and up directions at the midpoint of the network). In the listing file the rotations are listed in both ways.

Refraction coefficient

SNAP automatically applies atmospheric refraction corrections to zenith distance data. The correction is based upon a refraction coefficient, as defined by Bomford[1], and is the deflection of the light path divided by the angle subtended by the line at the centre of the earth. Commonly used values are 0.075 or 0.07.

---

[1]G.Bomford (1971), "Geodesy", Third Edition. Oxford University Press. Section 3.20, page 264

Each zenith distance observation has an associated refraction coefficient code, which defines the refraction coefficient to be applied. The default code is “DEFAULT”. You can use as many other codes as you wish. For example you may want to use codes “DAY” and “NIGHT” to apply different coefficients for daytime and nighttime observations. The refraction coefficient for each code can be specified in the command file, or it can be calculated by SNAP.

Distance scale error

With some distance measurements there may be a possibility of an undefined scale error in the measurements. For example one instrument may be suspected of introducing a scale error to all observations made with it. SNAP can apply a correction for scale errors to blocks of distance data. This is done in a similar manner to the way that refraction corrections are applied to zenith distance data.

Each scale error that you want to apply is given a name. In the data files you can associate a name with a group of distance measurements.

You can assign values to each scale error, and you can use SNAP to calculate best fitting values if you wish.

The scale errors are always expressed as a part per million error.

Reference frame scale error

The NZGD49 datum is considerably less accurate than modern survey equipment. In particular it contains scale errors of several part per million.

SNAP can include a “reference frame scale error” into the adjustment. In effect this allows all observations which define scale (distance observations and GPS baselines) to be scaled to be consistent with the datum.

The reference frame scale error is applied in addition to the GPS reference frame scale or the distance scale error that may apply to the data.

You can either define a value for the reference frame scale error, or you can let SNAP calculate the value best fitting the data.

Bearing orientation error

A “bearing orientation error” is a constant angular error applying to a group of azimuth or projection bearing observations. The error is measured in seconds of arc.

The main use for this error is in combining observations recorded from a number of survey plans. Each plan may have an orientation error resulting from the way the origin of the survey was established.

Each azimuth or projection bearing observation may have an associated orientation error code. Each code has an corresponds to an orientation error which may be either calculated or specified in the command file.

User defined systematic errors

You can use SNAP to calculate parameters other than those specifically defined in the adjustment. For example you may believe that an EDM is introducing an unknown constant error into the data. You can specify this in a data file by defining the systematic error, say as EDM_CONSTANT, and then defining it influence on each observation. If you want to calculate EDM_CONSTANT in millimetres, then its influence on each distance observation is 0.001 metres.

Systematic errors are implemented using the "systematic_error" and "data" data definition commands in data files, and the "systematic_error" command in the command file.

Observation classifications

The survey data used in a SNAP adjustment are automatically classified into groups based upon the type of data (horizontal angle, slope distance, ...) and upon the name of data file in which the data are defined.

SNAP allows you to specify other classifications of data in the data file. For example you can classify the data according to the equipment used or the type of GPS solution.

Data classifications are used for two things.

Firstly, you can exclude observations from the adjustment or reweight them based upon their classification (see the classification command, page 5-9). For example if you are doing a horizontal adjustment you can exclude all zenith distance data.

Secondly, you can summarize the residual errors in the data based upon the classification. (see the mde_power *power*

One additional column that can be included on the residual listing is the marginal detectable error (MDE). This is smallest error that will be flagged with a given confidence. The confidence that a bad observation will be flagged is termed the power of the test. The mde_power command defines this power. For example if the flag significance level (for the ?flag) is 95% and the MDE power is 80%, then the value that will be shown for an observation is the smallest error that there would need to be in the observation in order to be 80% confident that it would be flagged at the 95% significance level.

power Defines the power for which the marginal detectable error is calculated as a percentage.

config

summarize_errors_by command, page 5-18) For example you can output a summary of the standard errors accumulated for each data file, and within each data file accumulated for each data type. On the basis of this information you may rerun the adjustment with different input weights.

For details on how to define classifications for observations see “Classifying observations”, page 4-13.

Observation file format

Structure of an observation file

An observation file contains a header line, some “data definition commands” which describe what is in the file, and then the data themselves. This may be followed by further data definition commands, and another set of data. For example the first set of data may be a set of GPS vectors, and the second set distances and angles to offset stations.

The following example illustrates the layout of a typical SNAP data file.

`Demonstration data set`	Header line to describe the contents of the file
`#data sd` `#ds_error  10mm 2ppm`	Data definition commands (these start with a # character) The file will contain slope distances (SD) and the error associated with the distances is 10mm ± 2 ppm

`S01  1.31  S02  1.25`
`1051.822`
 	
`S01  1.31  S03  0.98`
`988.015`
	The first line of the data is for a line from S01 to S02. The instrument is 1.31 metres above S01 and the target is 1.25 metres above S02. The slope distance from the instrument to the target is 1051.822

`S01  1.31  S08  1.13`
`403.229`
 	
`S02  1.21  S01  0.95`
`1051.815`	

In this example there is just one data block which holds slope distance observations. However this could be followed by another data block containing horizontal angle observations.

Data definition commands are lines in the data file starting with the hash character (#). They are used to specify:

- the data types and format in the following data block
- the default errors that will be used for the data if none are defined explicitly
- the format of GPS errors
- data classifications and additional parameters (such as refraction coefficient) that apply to the data.

The data definition commands can throughout the file. In the data file illustrated above there may be a #ds_error command further down to specify a different error for the following distance observations, or there could be a #data command to specify that the following observations are horizontal angles.

Each data definition applies to the data following it until it is overridden by a subsequent data definition.

Following the data definition commands is a block of data.

The data can be formatted in four basic ways.

- point observation format: Each line contains an instrument station and the observations. This is used for observations such as latitude and longitude which involve just one station. The layout is:

  ```
  inst_stn_definition   observation   observation
  inst_stn_definition   observation   observation
  inst_stn_definition   observation   observation
  ........
  ```

- line observation format: Each line contains an instrument station, a target station, and the observations. This can apply for most data types except horizontal angles. The layout is:

  ```
  inst_stn_definition   trgt_stn_definition   observation   observation
  inst_stn_definition   trgt_stn_definition   observation   observation
  inst_stn_definition   trgt_stn_definition   observation   observation
  ........
  ```

- grouped observation format: The instrument station is entered on a header line, followed by several lines each defining a target station and the observations to it. This is used for horizontal angle data and multistation GPS data. It can also be used as an alternative to the line observation format for terrestrial data types such as distances and azimuths. The layout is:

```
inst_stn_definition
trgt_stn_definition  observation observation
trgt_stn_definition  observation observation
trgt_stn_definition  observation observation

inst_stn_definition
trgt_stn_definition  observation observation
trgt_stn_definition  observation observation
....
```

- grouped observation with covariance format: Organized as for grouped observations, but with a covariance or correlation matrix following each group. The covariance is separated from the data by a *#end_set* data definition command. This format is used for multistation GPS data. The layout is:

```
inst_stn_definition
trgt_stn_definition  observation
trgt_stn_definition  observation
trgt_stn_definition  observation
#end_set
covariance_matrix_elements ....
covariance_matrix_elements ....

inst_stn_definition
trgt_stn_definition  observation
trgt_stn_definition  observation
....
```

In the layouts above the items *inst_stn_definition*, *trgt_stn_definition*, and *observation* may each be composed of more than one data item.

The station definitions *inst_stn_definition* and *trgt_stn_definition* (instrument station definition and target station definition) define the station identifier (the station code from the coordinate file) and the height of the equipment above the station. The preceding #data command may specify that the height is to be omitted, in which case it is treated as being zero.

Each observation definition (*observation* in the layouts above) includes the value of the observation (e.g. the length for a distance measurement). It may also include the error of the observation, and additional information such as refraction coefficient codes, observation classifications, and so on. There may be more than one observation type on each line. For example a data block may hold readings from a total station which include horizontal angle, zenith distance, and slope distance. The contents of the observation section is defined in the preceding #data command.

The observation types can be classified into three groups. These are

- vector data: GPS baselines and multistation data
- point data: latitude and longitude observations
- conventional data: all other data types

Each data block can contain only one of these groups. So, for example, you cannot include GPS baselines (vector data) in the same data block as levelling data. However one data file can contain several blocks of data, which may be of different types.

Every observation must have an associated error. Errors can either be specified individually with each observation, or they can be defined for the entire data block in the data definition commands (as in the example above).

The data definition commands and observations do not need to be entered in specific columns. Each line consists of a number of items such as station names, observations, and so on separated by one or more spaces. If the information cannot be fitted onto a single line then it can be continued onto a second line by ending the first line with an ampersand “&” to indicate that there is more to follow.

Comments can be inserted anywhere into the data file. Comments are lines starting with an exclamation mark "!". These comments are ignored when the file is read. You can also add notes using the "#note" data definition command. Unlike comments, notes are saved with the data when SNAP reads the file, and may appear in the output listings.

Data definition commands

Data definition commands categorized by function

Data specification		
#data	4-10	Specify contents of data block
Observation errors		
#ds_error	4-12	Error of distance data
#ha_error	4-12	Error of horizontal angle data
#zd_error	4-12	Error of zenith distance data
#az_error	4-12	Error of azimuth data
#lv_error	4-12	Error of levelling data
#gps_enu_error	4-12	Error of GPS baselines
#gps_error_type	4-12	Format of GPS errors
#lt_error	4-12	Error of latitude observations
#ln_error	4-12	Error of longitude observations
Additional parameters of the data		
#refraction_coefficient	4-12	Define refraction coefficient code
#distance_scale_error	4-12	Define distance scale error code
#bearing_orientation_error	4-12	Define bearing orientation error code
#reference_frame	4-13	Define GPS reference frame code
Data classification		
#classification	4-13	Define a type of classification
#classify	4-13	Define classification for a data type
Miscellaneous		
#date	4-14	Define the date of observations
#time	4-14	Define the time of observations
#hp_angles	4-14	Subsequent angles will be HP format
#dms_angles	4-14	Angles will be degrees, minutes, seconds
#projection	4-14	Projection used for projection bearing data
#note	4-14	Attach a text note to an observation

Data definition commands listed alphabetically

Command	**Page**	**Description**
#az_error	4-12	Error of azimuth data
#bearing_orientation_error	4-12	Define bearing orientation error code
#classification	4-13	Define a type of classification
#classify	4-13	Define classification for a data type
#data	4-10	Specify contents of data block
#date	4-14	Define the date of observations
#distance_scale_error	4-12	Define distance scale error code
#dms_angles	4-14	Angles will be degrees, minutes, seconds
#ds_error	4-12	Error of distance data
#gps_enu_error	4-12	Error of GPS baselines
#gps_error_type	4-12	Format of GPS errors
#ha_error	4-12	Error of horizontal angle data
#hp_angles	4-14	Subsequent angles will be HP format
#ln_error	4-12	Error of longitude observations
#lt_error	4-12	Error of latitude observations
#lv_error	4-12	Error of levelling data
#note	4-14	Attach a text note to an observation
#projection	4-14	Projection used for projection bearing data

Command	**Page**	**Description**
#reference_frame	4-13	Define GPS reference frame code
#refraction_coefficient	4-12	Define refraction coefficient code
#time	4-14	Define the time of observations
#zd_error	4-12	Error of zenith distance data

The #data command

#data *options [data_type data_items] [data_type data_items] ...*

The #data command lists the observations that will appear after each target station. Each observation is represented by a data type code (such as SD for slope distances) and one or more data items defining the fields (such as errors, classifications, and so on) that make up the observation.

The #data command may also include options defining overall characteristics of the data format. The options can be placed before or after the data items. The available options are:

grouped — specifies that the data layout is as for grouped data. This is redundant if the data includes observations which force grouping (horizontal angles and distance ratios).

no_heights — specifies that the instrument and target station definitions do not include a station height (it is assumed to be 0).

Each observation is represented by a data type and some data items. For example distance data may include the measured slope distance, the error in the distance, and the equipment classification of the distance. In the data definition this would look like

```
#data  no_heights sd error equipment
```

and in the data block the data could be

```
STN1 STN2  1234.567 0.002  DI20
```

If an observation is unavailable then it can be replaced in the data file with a hyphen “-”. This is useful in a data block with more than one observation per line. For example each line may contain an angle and a distance observation. If the distance to one station is not measured then it can be replaced by a hyphen. The hyphen replaces all the data items relating to the observation. For example the data definition could specify that each line contains a horizontal angle, a slope distance, and the error of the slope distance. The definition would be

```
#data no_heights ha sd error
```

and the corresponding data block could include

```
STN1
STN2     0 00 00.0   1234.45  0.03
STN3    58 02 25.3         -
STN4    89 08 37.5    987.65  0.02
```

Here the distance from STN1 to STN3 is missing. (Note that this example the data is in grouped format because it includes horizontal angle data).

The available data types are listed in the table below.

The data type may be followed by any of the following items.

value — the measurement itself. The “value” item can be omitted if it is the first item after the data type. In the data block, this field is read as an optional '*' (indicating a rejected observation), followed by the measurement, followed optionally by the word "error" and the error of the measurement.

error	the error of the measurement. If this is not specified then current default error for the data type is used (as specified by data definition commands listed below). The units of the error in the data block is listed in the following table.
time	the time of the measurement formatted as hh:mm or hh.mm.
distance_scale_error	the distance scale error code for the measurement (only applies to distance data)
refraction_coefficient	the refraction coefficient code for the measurement (only applies to zenith distance data)
bearing_orientation_error	the bearing orientation error code for the measurement (only applies to azimuth and projection bearing data)
classification	The data item is the name of a classification of the data (e.g. EQUIPMENT). This classification must already be defined in the data file by a #classification command (see below). The data block should contain the corresponding classification of the measurement (e.g. T2). See page 4-13 for an example of this.
systematic_error	The data item is the name of a systematic error. The data record contains the influence of the systematic error on the observation.

Observation type	Code[1]	Units	Format[2]	Default error command[3]
slope distance	SD	metres	line/grouped	#ds_error
horizontal distances	HD	metres	line/grouped	#ds_error
ellipsoidal distances	ED	metres	line/grouped	#ds_error
distance ratios	DR	metres	grouped	#ds_error
horizontal angles	HA	arc sec[4]	grouped	#ha_error
zenith distances	ZD	arc sec[4]	line/grouped	#zd_error
azimuths	AZ	arc sec[4]	line/grouped	#az_error
projection bearings	PB	arc sec[4]	line/grouped	#az_error
levelling data	LV	metres	line/grouped	#lv_error
observed longitude	LN	arc sec[4]	point	#ln_error
observed latitude	LT	arc sec[4]	point	#lt_error
GPS baselines	GB /GPS	metres	line	#gps_enu_error
GPS multistation	GB /GPS	metres	grouped /covar	#gps_enu_error

1 The code is used to identify the observation type in the #data command

2 The format refers to the layout of the data block; point format, line format, grouped format, or grouped with covariance format

3 The default error command is the command used to specify errors of observations that are not explicitly specified for each observation

4 Angle observations are in degrees minutes and seconds (either as three separate numbers or in “HP” format.

Specifying observation errors

#ds_error *value* mm *value* ppm

This defines the default error that applies to subsequent distance data (slope or horizontal distances). The error is defined by a millimetre component and a part per million component. The total error is calculated from the square root of the sum of the squares of these components. For example if a the error was defined as "3 mm 2 ppm", then the error on a 2000m line would be 5 mm.

#ha_error *value* sec
#zd_error *value* sec
#az_error *value* sec

These define the default error in seconds for subsequent horizontal angle, zenith distance, and azimuth data. Projection bearings are assigned the same errors as azimuth data.

#lv_error *value* mm

This defines the default error to be used for levelled height differences.

#gps_enu_error *value value value* mm *value value value* ppm

This specifies the default error for GPS vector differences. The error is specified by a millimetre and part per million components in the east, north, and up directions. SNAP assumes that there is no correlation between these directions. The error of each component is the root sum of squares of the millimetre and part per million errors. For more detail see "GPS error formats", page 4-14.

#gps_error_type *type*

If you are explicitly defining the errors for each GPS observation rather than using default values then the gps_error_type defines the format they are entered in. *type* can be one of "full" (the default), "correlation", "diagonal", and "enu" (east, north, and up components). GPS error formats are discussed more fully below (see "GPS error formats", page 4-14).

#lt_error *value* sec
#ln_error *value* sec

Specifies the default errors for latitude and longitude observations in seconds of arc.

Additional parameters of the data

#refraction_coefficient *name*

This specifies what refraction coefficient will be used for subsequent zenith distance data. If none is specified then a coefficient named "default" is used.

#distance_scale_error *name*

This specifies the name of the distance scale error that applies to subsequent distance data in the file. If it is not specified then no distance scale error is applied. Use the name "none" to cancel the distance scale error for subsequent observations.

#bearing_orientation_error *name*

This specifies the name of the bearing orientation error that applies to subsequent azimuth or projection bearing data. If this is not specified then no bearing orientation error is applied. Use the name "none" to cancel the error for subsequent observations.

#reference_frame *name*

Defines the reference frame in which GPS observations have been measured. The default name is "GPS".

Classifying observations

#classification *name*

This command specifies that subsequent data may be classified using a classification called "name". In order to use this classification it must be defined for subsequent observations using either the #classify command, or by including the classification name in a #data command. An example of a classification name would be "equipment".

#classify *[data_types] classification value*

This specifies the value for a classification that will be used for subsequent observations. For example, it may be used to indicate that the "equipment" for the following distance observations is "DI20".

data_types	specifies the observation types for classifications. This can include one or more of the data types as listed for the #data command. If more than one type is to be specified, the codes should be separated by "/" characters. For example "SD/HD" indicates that the classification will apply for slope distances and horizontal distances.
classification	is the name of the classification being defined, for example "equipment". This need not have been specified in a #classification command - SNAP will create a new classification if necessary.
value	is the value to be used. For example this might the name of the equipment.

The following extract from a data file shows how the classification commands are used. In this case we are defining a classification called "CONDITIONS". This will be set to "GOOD", "FAIR", or "BAD" according to how the conditions seemed to the observer. When we analyse the data we will be able to determine how the residuals in "GOOD" conditions compared with those in "BAD" conditions, and we will be able to easily modify the weighting of the data according to these conditions.

```
! Define a classification called conditions
#classification conditions
! For all subsequent horizontal angles the conditions will be  UNKNOWN
#classify HA conditions unknown
! Some horizontal angle data
#data ha no_heights
#ha_error 1 sec
1
2     0 00 00.0
3....35 12 52.3
! For distance data we want to specify classifications individually
#data sd conditions no_heights
#ds_error 5 mm 1 ppm
1  2  1201.232  good
1  3   955.081  bad
```

Miscellaneous data definition commands

#date *date*

Specifies the observation date of the following data. *date* should either be a date formatted as day number, first three letters of month, year (e.g. 12 Jun 1992), or the word “unknown”.

#time *time*

Specifies the observation time of the following data. *time* should be formatted as hours and minutes separated by a semicolon (e.g. 15:30).

#hp_angles
#dms_angles

These commands specify the angle format used for subsequent horizontal angle, zenith distance, azimuth, and projection bearing data. *#hp_angles* specifies that the angles will be represented in the format commonly used by Hewlett-Packard calculators. This is as a single number representing degrees by the digits before the decimal place, minutes by the two digits after the decimal places, and seconds by the next two digits. Additional digits are the decimal part of the seconds (i.e. DDD.MMSSss). *#dms_angles* specifies that angles are represented as three numbers, the degrees, minutes, and seconds separated by spaces (i.e. DDD MM SS.ss). By default the *#dms_angles* format is used.

#projection *code*

Defines the projection in which projection bearings are defined. *code* is the code of a coordinate system defined in COORDSYS.DEF (see “Coordinate system definition”, page A-1). SNAP will only accept the data if this code defines a projection (that is, not a geocentric or latitude and longitude coordinate system) that can be converted to the station file coordinate system.

#note *text*

Attaches the text to the following observation. This text remains with the observation, and can be included on output listings. This is particularly useful to identify observations for which problems are expected, or which have been rejected.

GPS error formats

Errors of GPS baseline and multistation data can be expressed either by a data definition statement #gps_enu_error, or explicitly for each vector.

The format for the #gps_enu_error data definition command is

#gps_enu_error *value value value* mm *value value value* ppm

The error is expressed as the millimetre and part per million errors for the east north and up components of the vector. SNAP assumes that there is no correlation between the components or between the millimetre and part per million errors. The part per million error is calculated from the total length of the baseline, not from components of the lengths in the east, north and up directions. Suppose that the vector is 10 km long and the north error is defined as 3ppm ± 40mm. The part per million error is 3ppm × 10km = 30mm. The standard error of the north component of the vector is thus $\sqrt{}(30^2 + 40^2) = 50$mm.

Multistation data is entered as a set of baselines measured from a reference station. However any of the stations in the set could have been used as a reference station. The #gps_enu_error specifies the error between any two stations in the set. SNAP calculates the correlation between the vectors such that any vector calculated between two target stations has the correct error.

For example the multistation data may give the vectors to stations B and C from station A. The #gps_enu_error defines the errors of A-B and A-C, and the correlation between them. From this information it is possible to calculate the errors of the vector from B-C. The correlations are calculated so that the errors on this vector match the values specified in #gps_enu_error command for a vector of that length.

For baseline data the default values for the error can be overridden for a specific vector. This is done by following the value of the vector by the word “error” and then the east, north, and up components of the error in metres. For example a vector between STN1 and STN2 could be entered as

```
STN1  STN2  93.0 1234.4 -888.0  error 0.03 0.06 0.09
```

Errors cannot be overridden for multistation data because there is no convenient way of describing the correlation of the modified vector with each other vector in the set.

GPS errors are entered explicitly for each vector if the #data data definition command includes “error” with the definition of the GPS observation. The format used to express the error is defined by the #gps_error_type data definition command. The format also differs between baseline data (line format) for multistation data (grouped data format).

For baseline data the errors of each vector are listed with the observation. The format defined by #gps_error_type can be one of “full” (the default), “correlation”, “diagonal”, or “enu”. The data required for each format is as follows:

- full: The error consists of 6 elements of the covariance matrix of the XYZ components in the order

  ```
  Cxx Cyx Cyy Czx Czy Czz
  ```

- correlation: The error consists of the standard errors of the XYZ components followed by their correlations

  ```
  Sx  Sy  Sz  cyx  czx  czz
  ```

- diagonal: The error consists of just the standard errors of the XYZ components, with the correlations assumed to be zero. This is generally not a realistic model. The error is formatted as

  ```
  Sx  Sy  Sz
  ```

- enu: The error consists of the standard errors in the local east, north, and up coordinate system. Correlation between the components is assumed to be zero. The format is

  ```
  Se  Sn  Su
  ```

In all cases covariances are expressed in metres squared, and standard errors in metres.

For multistation data the errors must express the correlation between the vectors as well as between the components of each vector. This is done with the “grouped with covariance” format. That is, the set of observations is followed by a covariance matrix. The covariance matrix starts with a data definition command “#end_set”, which marks the end of the data. Subsequent lines contain the matrix values. These values may be spread over as many lines as are required.

Errors of multistation data can be expressed in any of the four formats listed above. However the “diagonal” and “enu” errors are not generally appropriate, as they cannot express the correlations between the baseline vectors.

For the “full” format the lower triangle of the covariance matrix follows the set of observations. The rows of the matrix represent the X, Y, and Z components of the first vector, then of the second vector, and so on. The order of elements is thus

```
C(x1,x1)
C(y1,x1) C(y1,y1)
C(z1,x1) C(z1,y1) C(z1,z1)
C(x2,x1) C(x2,y1) C(x2,z1) C(x2,x2)
C(y2,x1) ....
```

where C(x2,y1) represents the covariance between the x component of the second vector and the y component of the first.

For the "correlation" format the standard errors of the XYZ components of the vector are listed on the same line as the vectors as three numbers (Sx, Sy, Sz). The set of observations is followed by the lower triangle of the correlation matrix. In this case the leading diagonal of the matrix is omitted, since each element must be 1. The order of elements in the matrix is thus

```
c(y1,x1)
c(z1,x1) c(z1,y1)
c(x2,x1) c(x2,y1) c(x2,z1)
c(y2,x1) ....
```

where c(x2,y1) represents the correlation between the x component of the second vector and the y component of the first.

Rejecting data

Often after the data has been adjusted some of the observations appear to have large residual errors. That is, they do not fit will with the other observations and the fixed stations. A common practice is to redo the adjustment without using the suspect observations. In SNAP you can exclude the observations from the adjustment without removing them from the data file. These observations are still listed in the output file and their residual errors are still calculated.

To reject an observation from an adjustment the data should be preceded by an asterisk "*". Here is an example of a rejected observation:

```
#data sd equipment value error no_heights

STN1 STN2   DI20 *1234.56   0.002
```

Note that the asterisk precedes the "value" part of the observation.

Observations can also be rejected by putting the asterisk at the beginning of a line. For example:

```
* STN1 STN2 DI20  1234.56 0.002
```

If the line contains more than one observation then putting the asterisk at the beginning of the line rejects them all.

When rejecting observations you should try and identify a reason why the observation could be in error. It is good practice to put this information into a note in the data file. For example:

```
#data ha no_heights

STN1
STN2     0 00 00.0
#note  Observer had difficulty identifying target
#note   (See field book 101/3 page 15)
STN3  *30 00 23.4
```

Example data file

The following example show how a data file is structured.

```
SNAP demonstration data set

# date 12 May 1992

! Example of distance and horizontal angle data

# data sd ha

# ds_error 10 mm 2 ppm
# ha_error 2 sec

# classify SD EQUIPMENT DI20
# classify HA EQUIPMENT T2

! Note that the default errors have been overridden for
! two observations.  Also note that one distance is missing.

!From To  H.I.    Distance    error      Direction   error

 1        1.55
      2   1.30    21110.75                0 00 00.0
      3   1.15        -                  15 23 16.8  error 5
      4   1.20    17967.48  error 0.03   48 58 07.2

! The distance to station 1 is rejected in the following set

 4        1.20
      3   1.62    21314.218               0 00 00.0
      5   1.34    14296.911              70 18 54.6
      1   1.03 *  17969.434             241 23 01.2


! Example of gps baseline data

# data gps no_heights

# reference_frame GPS
# gps_enu_error 15 30 50 mm

! From  To        X           Y          Z

  1     2     -399.32    20958.80    2497.10
  1     3    -6943.55    31476.72   10172.31
  1     4    -8808.29    10306.10   11790.89

! Example of multistation GPS data

#data gb error grouped no_heights
#gps_error_type full

1
  5       16688.7857  -109992.9680   -34179.4465
  6        5782.9042  -128377.1792   -25222.3289
#end_set
  2.52189989E-05
 -3.51365053E-06  1.45083257E-06
  1.99479380E-05 -2.27106609E-06  1.93004819E-05
  6.20761587E-06 -8.96910370E-07  5.36535610E-06  2.28536949E-05
 -9.00332437E-07  3.24931104E-07 -7.97373532E-07 -2.45152986E-06
  9.70341277E-07
  5.34392361E-06 -7.91887378E-07  5.21602684E-06  1.94275136E-05
 -2.10103471E-06  1.87209786E-05

! Example of point format (lat and long) data

#date unknown
# data lt error ln error no_heights

!      Latitude     Error     Longitude     Error

1     41 19 06.32 S   0.1        -
3     41 11 38.20 S   0.1   175 23 55.35 E   0.1
```

Troubleshooting data file errors

When you create data files by typing information in from field books you may make errors which will prevent SNAP from being able to correctly read the file. If this occurs SNAP will create a list of errors relating to the file. Each error message includes a description of the error, the name of the data file, and the line number at which the error was detected.

An example of an error is:

```
Error: File: testerr.dat   Line: 9
    Invalid error definition - use syntax #ha_error #.# sec
```

In this case the error occurred at line 9 of the file testerr.dat. The error message indicates that the syntax of the #ha_error command is incorrect and gives an example of how it should be formatted. (This is a likely error when using data files from version 1 of SNAP, in which the angle units could be entered as "secs" or "seconds")

Here are some common error messages and explanations of what they mean.

Definition of data format missing - use #data

This occurs if the program encounters a line of data before the first #data command. SNAP requires a #data command to define the format of the data, and so it cannot interpret the input. To fix this problem ensure that a #data command precedes the first line of data in the file.

Invalid data definition command "#*****"

SNAP has encountered a data definition command that it cannot interpret. This is most likely because the command has been misspelled.

Field "*****" invalid or out of place in #*****

The named field cannot be part of the specified data definition command. The most likely reason is that the field has been misspelled.

No data is specified in #data

A #data command does not define any data items. Every #data command must define at least one data type to be loaded. The #data command needs to be corrected.

***** obs not compatible with *****

The #data command includes two types of data which cannot be combined. For example it could specify both GPS data (vector data) and slope distance data (line data). The data will need to be split up into two separate data blocks to fix this.

Cannot combine **** with other observations

The named observation type must be the only data item in a data definition command (currently this applies only for GPS data).

Invalid error definition - use syntax *******

An error definition is not correctly formatted. This error message lists the correct syntax for specifying the error.

Error of ****** not defined - use #****

The data block includes data for which an error is not explicitly defined (that is, the error is not listed individually with each observation) and for which no default error has been defined. The error message will indicate the data definition command needed to specify the error (e.g. #ha_error). The specified command must be inserted before the data.

Missing or invalid projection - check #projection in data file

The data includes projection bearings, but no projection has been defined in the data file (there is no #projection command), or the #projection command defines a coordinate system which is not a projection, or the projection cannot be transformed to the coordinate system of the station file.

Invalid ***** station code "****"

The data file specifies a station code which is not listed in the coordinate file. This may be because the code is incorrectly entered, or because the station has been omitted from the coordinate file. You can use the ignore_missing_stations command in the command file to skip data for which the stations are not defined.

Invalid or missing *****

An item is missing from an input line, or is incorrectly formatted. This is usually because the items in a data block do not match those specified in the preceding #data command.

Extra data in data file

A line in a data block contains more items than expected from the preceding #data command. To fix this identify and remove the extra items or correct the #data command.

The ***** matrix is missing

For GPS multistation data - the covariance or correlation matrix is missing. This may be because the set of observations is not separated from the matrix by a #end_set command, or it may be because the matrix is missing.

Chapter Five: Command files and Configuration files

Introduction

What is a command file

The command file instructs SNAP what to do. It defines the coordinate and data files, the program options, and the output options.

There are about 45 different commands that can be used in the command file. However the only commands that are required are:

- title: defining the title of the job
- mode: defining what is to be done
- coordinate_file: defining the coordinate file
- data_file: defining the data to be used

Usually you will also want to specify some stations to be held fixed with the "fix" command. Here is an example of a command file using just these commands:

```
title Demonstration SNAP adjustment
!
! The name of the coordinate file.
coordinate_file  demo.crd
!
! Data files - in this case there are two
data_file  demo.dat
data_file  demogps.dat
!
! Do a three dimensional adjustment
mode 3d adjustment
!
! Fix stations TrigX and 1150, and fix the height of
! BM328
fix  TrigX  1150
fix vertical  BM328
```

What is a configuration file

Many of the commands that you can put into a command file are to select options which you want to apply every time you run SNAP. For example you may want a different output format from the default. In SNAP you can do this by creating one or more configuration files. These files contain commands to change the default options of SNAP.

Configuration files differ from command files only in that they cannot contain commands specific to an adjustment. For example they cannot specify data files, or fixed stations.

SNAP may use several configuration files before running an adjustment. The files it will try to use are:

- SNAP.CFG in the same directory as the SNAP program.
- SNAP.CFG in the user's directory. This directory is defined using either the SNAPDIR environment variable, or the -u option on the SNAP command line.
- SNAP.CFG in the same directory as the command file

SNAP will check for the existence of each of these files and use it if it exists.

You can also specify additional configuration files within the command file. This can be used to easily change options for different types of adjustment. For example, you may want different listing formats for trial adjustments and for the final adjustment. You can put the options into configuration files called "TEST.CFG" and "FINAL.CFG". Then in the command file you only need to enter the command "configuration TEST" or "configuration FINAL" to select the options.

SNAP will look for named configuration files in the following places:

- the same directory as the command file
- the user's directory. This directory is defined using either the SNAPDIR environment variable, or the -u option on the SNAP command line.
- the same directory as the SNAP program

If the file is found in more than one of these directories the first one found is used.

config In the following sections the commands that can be used in configuration files are denoted by the word "config" in the left margin.

Command syntax

Each line of a command or configuration file is an instruction to SNAP. It consists of a command followed by a list of parameters. For example the coordinate file may be specified by the command

```
coordinate_file   job52.crd
```

Here the command is "coordinate_file" and it has one parameter "job52.crd".

Blank lines in the command file are ignored. Also any information after an exclamation mark (!) on a line is ignored. You can use the exclamation mark to include comments in the command file.

The following sections list the commands that can be used. Note that some commands include the underscore character. This must not be omitted. Many commands can be repeated as often as required. For example there should be a separate data_file command for each data file in the adjustment. Some commands, such as coordinate_file, cannot be used more than once in a command file.

In the following descriptions of commands brackets [] are used to signify parts that are optional. Parameters in italics are items that must be replaced with sensible information. For example, the definition of the data file command is

data_file *data_file_name* [*format*] [error_factor *value*]

In this command the items [*format*] and [error_factor *value*] can be omitted. The items *data_file_name*, *format*, and *value* must be replaced by the user. So in a configuration file the command might look like

```
data_file 1530.dat  error_factor 1.5
```

Here *data_file* has been replaced with 1530.dat, and *value* has been replaced with 1.5. The format parameter has been omitted.

Summary of commands by function

Command	Page	Description
Station selection		
coordinate_file	5-7	Define coordinate file
topocentre	5-7	Define network topocentre
fix	5-7	Define fixed stations
free	5-7	Define free (not fixed) stations
float	5-8	Define floated stations
horizontal_float_error	5-8	Set horizontal error for float stations
vertical_float_error	5-8	Set vertical error for float stations
reject	5-8	Define rejected stations
ignore	5-8	Define ignored stations
accept	5-8	Define accepted (not rejected) stations
ignore_missing_stations	5-8	Allows missing stations in data files
Input data		
data_file	5-8	Define a data file
classification	5-9	Define handling of classifications
gps_vertical	5-9	Define handling of GPS covariances
use_distance_ratios	5-10	Define handling of distance ratio data
Additional parameters		
refraction_coefficient	5-10	Define handling of refraction coefficients
distance_scale_error	5-10	Define handling of distance scale errors
bearing_orientation_error	5-10	Define handling of bearing orientation errors
systematic_error	5-10	Define handling of systematic errors
reference_frame_scale_error	5-10	Define the reference frame scale error
default_refraction_coefficient	5-11	Set the default refraction coefficient
reference_frame	5-11	Define handling of GPS reference frames
Adjustment options		
mode	5-12	Set the adjustment mode
convergence_tolerance	5-13	Set the convergence tolerance
max_iterations	5-13	Set the maximum number of iterations
max_adjustment	5-13	Set the maximum change to a station position
reorder_stations	5-13	Define handling of bandwidth minimization
deformation	5-13	Include a deformation model in the adjustment
Output options		
title	5-14	Define job title for output
list	5-14	Define options for list file
print	5-14	Define options for list file
output	5-16	Define additional output files
define_residual_format	5-16	Define the layout of the residual listing
add_residual_column	5-16	Modify the layout of the residual listing
output_precision	5-16	Define the precision of data in the listing
coordinate_precision	5-16	Define the precision of listed coordinates
sort_observations	5-16	Define how observations are sorted
station_code_width	5-17	Define number of characters in station code
file_location_frequency	5-17	Define source location information in listing
number_of_worst_residuals	5-17	Define number of bad residuals identified
flag_significance	5-17	Set significance at which residuals are flagged
redundancy_flag_level	5-18	Set maximum redundancy that is flagged
mde_power	5-18	Set the power of the MDE
summarize_errors_by	5-18	Define error summary
error_type	5-18	Define error type, apriori or aposteriori
Testing accuracy specifications		
specification	**5-21**	Define a relative accuracy specification
test_specification	5-21	Define which stations to test
spec_test_options	5-21	Define options controlling the tests
Miscellaneous commands		

Alphabetic list of commands

Specifying stations to adjust

Fixed, free, and floating stations

When you adjust survey data you usually need to supply constraints on one or more stations in order to obtain a solution. SNAP provides two methods for constraining stations. These are:

- Fixing stations: The coordinates of the station are not altered in the adjustment. In a 3d adjustment a station can be fixed horizontally, vertically, or in all directions.
- Floating stations: A floating station is one for which the initial coordinates are held fixed with a specified tolerance. The initial station coordinate is treated not as a constraint, but as an observation with a specified error. Again stations can be floated horizontally, vertically, or in all directions. You can specify different errors for the horizontal and vertical coordinates.

Note that floating station coordinates are treated as observations and do affect the statistics coming from the adjustment. For example if you give the floating stations a very large tolerance then the residuals on the station coordinates will tend to be small, and will result in a smaller standard error of unit weight.

Accepted, rejected and ignored stations

You can also choose to reject stations or ignore stations. If a station is rejected from the adjustment then it is not adjusted and none of the data relating to that station are used in the adjustment. However the observations are still listed in the output file with residual errors.

If you ignore a station then it, and any data relating to it, are completely removed from the adjustment and from all output files.

SNAP will automatically reject stations which have not been observed. It will also reject stations for which there are fewer observations than the number of coordinates to be calculated. For example in a 2d adjustment a station with just one observation to it will be rejected. There may still be stations which are not rejected, and yet which cannot be adjusted with the data supplied. For example there could be a station connected to the network by three distance observations all to the same station. This would not be rejected by SNAP even though its position cannot be calculated. In this case the adjustment will be singular and the error listing from the adjustment will indicate which station is causing the problem.

Station lists

Several commands (for example reject, ignore, fix) use a list of station codes to identify the stations that are affected. This list can include stations codes, ranges of station codes, and references to station list files.

Ranges of stations are entered as two station codes separated by a hyphen (for example “5-15”). The range cannot include any blank characters. If it is entered as “5 - 15” it will be interpreted as three stations, “5”, “-”, and “15”. Also if there is actually a station called “5-15” then this will be interpreted as referring just to the station rather than defining a range.

In order to use station ranges the station codes are ordered numerically using the leading digits in the code, and then alphabetically using any remaining characters in the code. Using this scheme the range “5-15” would include “10” and “10A”, but not “100”. Note that the range has nothing to do with the order of stations in the coordinate file.

When a group of stations will be referenced several times it may be convenient to put the list into a separate file. For example if you wanted to be able to easily exclude all benchmarks from an adjustment, you could create a file called BENCHMRK.LST. In this you would specify all benchmarks. Then in the command file you would include the command

reject @benchmrk.lst

to reject them.

A station code list file may contain any number of station codes and station code ranges. It cannot include references to other list files. The codes can be spread over several lines. They should be separated by blank characters. The file can include comments as lines starting with the character “!”.

Commands

coordinate_file *coord_file_name [format]*

Defines the name of the station coordinate file. The optional format defines alternative formats for the coordinate file. Currently the only format supported is the SNAP default format, and the format used by DOSLI geodetic software. To use DOSLI format files *format* should be "GB".

topocentre *latitude longitude*

Defines the topocentre of the network. This may be used to convert reference frame rotations and GPS errors between topocentric and geocentric reference frames. If no topocentre is defined then SNAP will calculate a midpoint based upon the extents of the coordinates in the data file. *latitude* and *longitude* should be entered in decimal degrees, for example

topocentre -41 170

fix [*type*] [all] [*station_list*]

Defines which stations are to be held fixed in the adjustment. This command cannot precede the coordinate_file command. By default all stations are adjusted if there are adequate observations to them. The parameters are:

type	specifies which coordinates are to be fixed. It can be one of "horizontal", "vertical", or "3d". If the *type* is omitted then all the station coordinates are held fixed.
all	may be included if you want to fix all stations. You can then use the free command to select a few stations that are to be adjusted. (This is useful if you only want to adjust a few stations).
station_list	is a list of stations to be held fixed separated by blank spaces.

Here are some examples of the fix command

fix all

fix 1 5 23

fix horizontal 1A BM3 50-55

fix vertical 3 4 5A

free [*type*] [all] [*station_list*]

The free command defines stations that are to be adjusted. It is most useful after the "fix all" command to specify just a few station that are to be adjusted (for example calculating a resection).

The command parameters are identical to those of the fix command.

float [*type*] [all] [*station_list*]

Defines stations that are to be floated (i.e. their current location is used as an observation with a specified tolerance).

The options are identical to the fix command. The horizontal and vertical errors applied are the current defaults for the command file. Initially values of 1 metre are used for each. They are changed with the horizontal_float_error and vertical_float_error commands described below. An example of the use of these commands would be

```
horizontal_float_error  0.5
vertical_float_error  1.0
float  horizontal  bm3  stn4
float vertical  stn8 stn9
float stn7
```

horizontal_float_error *error*

Defines the horizontal error that will be used for subsequent float commands. *error* should is the error in metres.

vertical_float_error *error*

Defines the vertical error (in metres) that will be used in subsequent float commands

reject [all] *station_list*
ignore [all] *station_list*
accept [all] *station_list*

Defines stations that are to be rejected, ignored, or accepted from the adjustment. Rejected station are not used in the adjustment, and observations to or from them are treated as rejected. Ignored stations are removed from the adjustment. Neither the stations nor any observations pertaining to them appear in the SNAP output. The accept command cancels reject or ignore commands. To select just few stations use “ignore all” and then accept the stations of interest.

all	if present specifies that all stations are affected
station_list	is a list of stations to be affected.

config

ignore_missing_stations [yes|no]

This command instructs SNAP to ignore station codes in the data file which are not listed in the coordinate file. The missing stations will be listed in the error file. If this command is not used then SNAP will report all missing stations in the data files and stop the adjustment.

Specifying the input data

Commands

data_file *data_file_name* [*format*] [error_factor *value*]

Defines the name of a data file. This command can be repeated as many times as required to specify all the data files being used. The parameters of this command are:

data_file_name	The name of a data file. Each data file needs a separate data_file command.
format	is required only for files which are not in SNAP format. Currently SNAP only supports its own format and the format used by the DOSLI geodetic software. To use the geodetic files *format* should be "GB".
value	is a factor by which all observation errors in the file are multiplied.

Examples of this command are

```
data_file  traverse.dat
data_file  1614.ha gb error_factor 1.5
```

classification *type* [ignore] [reject] *name* [error_factor *value*]

The classification command is used to modify input data based upon its classifications (see "Observation classifications", page 4-6). The actions that can be done are to ignore or reject the data, or to apply a scale factor to its error. The parameters are

type	The type of classification. This can be "data_type", "data_file", or a user defined classification, such as "EQUIPMENT".
ignore	If present then the data with the specified classification are completely ignored.
reject	If present then the data with the specified classification are not used in the adjustment, but their residuals are listed.
name	The value of classification which is affected, for example "T2" for classification "EQUIPMENT".
value	A scale factor applied to the errors for the data.

Here are some examples of classification commands. This command causes all zenith distance data to be ignored.

```
classification data_type ignore ZD
```

The following command change the weighting applied to horizontal angle data and to data with its equipment classification set to "T2".

```
classification equipment T2 error_factor 0.5
classification data_type HA error_factor 3
```

With these two commands a horizontal angle with equipment classification "T2" will have both error factors applied to it. That is, the error in the data file will be multiplied by 0.5 and by 3.

config

gps_vertical *location*

Defines how GPS covariances are transformed from topocentric components to geocentric components and vice versa. By default SNAP uses a single rotation matrix based on a central point of the network. The reference point in the network can be specified with the "topocentre" command (see above, page 5-7). You can require that SNAP calculate a rotation matrix individually for each baseline.

location	can either be "topocentre" for default behaviour, or "midpoint" to use the midpoint of each baseline.

For example:

gps_vertical midpoint

use_distance_ratios *option*

This command specifies whether distance ratio data are to be processed as distance ratios, or treated as independent distance observations. The parameter of the command is:

option	can be "yes" or "no". If it is "yes" (the default) then sets of distance ratio data are processed as dependent observations with a common scale factor. If it is "no" then they are treated as independent slope distance observations.

Calculating or setting additional parameters

Many observations may depend upon parameters other than that station coordinates. For example zenith distance observations depend upon the refraction coefficient. These extra parameters are described in the previous chapter (see "Additional parameters of observations", page 4-4).

The values of the parameters are not entered in the data file. Instead each observation is assigned a code corresponding to the value of the parameter. There can be several different codes for each parameter. For example there may be refraction coefficient codes "DAY" and "NIGHT".

The command file defines how SNAP is to treat each code. In the command file you can

- specify the value for a code (for example refrection_coefficient DAY 0.08)
- specify that the value is to be calculated as part of the adjustment
- specify that one or more calculated codes have identical values. For example you may want to compare an adjustment in which DAY and NIGHT coefficients are allowed different values to one in which they have the same value

Commands

refraction_coefficient [calculate] *code* [*value* [?]]
distance_scale_error [calculate] *code* [*value* [?]]
bearing_orientation_error [calculate] *code* [*value* [?]]
systematic_error [calculate] *code* [*value* [?]]
reference_frame_scale_error [calculate] [*value* [?]]

These commands specify how the refraction coefficients, distance scale errors, bearing orientation errors, user defined systematic errors, and reference frame scale error are calculated. The parameters of the commands are:

calculate	If present, specifies that the value of the named refraction coefficient is to be calculated in the adjustment
code	Is the code of the additional parameter. If the code ends with an asterisk "*" then any code matching the beginning of the code will be affected. For example, if a refraction coefficient code is specified as DAY* then the command will apply for any refraction coefficient starting "DAY". Codes such as DAY, DAY_ONE, and DAYTIME would be affected.
value	Is the initial value used for the coefficient. If it is followed with "?" then the value will be calculated

(equivalent to the "calculate" keyword). If the parameter is being calculated then the value specified is used as an initial trial value.

Examples would be

```
refraction_coefficient * 0.08
refraction_coefficient calculate DAY
distance_scale_error  DI20 0.5 ?
reference_frame_scale_error calculate
```

refraction_coefficient *code1 = code2*
distance_scale_error *code1 = code2*
bearing_orientation_error *code1 = code2*
systematic_error *code1 = code2*

Specifies that two or more codes will be treated as identical in the adjustment. The effect of this command is that the additional parameter (or parameters) corresponding to *code1* are made identical to *code2*. Furthermore, if *code2* is being adjusted, then all the codes will be adjusted to the same value. Note that the "=" must be surrounded by spaces.

code1 The code of parameters that are to be modified. This can end with a "*", in which case any parameter matching the start of code1 is affected.

code2 The parameter that the *code1* parameter is being matched with.

For example to do an adjustment in which all the refraction coefficients are treated equally, use the commands

```
refraction_coefficient calculate DEFAULT 0.075
refraction_coefficient  *  =  DEFAULT
```

config **default_refraction_coefficient *value***

This command defines a value that will be used for refraction coefficients codes that occur in the data file and are not specified by a "refraction_coefficient" command. The command is equivalent to "refraction_coefficient * value"

value Specifies the value that will be used for subsequently defined refraction coefficients. The default value is 0.075.

reference_frame [*type*] [calculate] *code parameter* [*value* [?]]

Defines the reference frame parameters for GPS vectors.

type may be "geocentric" or "topocentric". The default is topocentric.

code is the code of the reference frame.

parameter may be "scale" or "rotation"

value is the value associated with the parameter. For rotations and translations there are three values corresponding to the X, Y, and Z axes for geocentric reference frames, or the East, North, and Up axes for topocentric systems. The scale is specified as ppm and the rotations in arc seconds. Each value can be followed by a ? to indicate that it should be calculated.

Note that the reference frame type (topocentric or geocentric) is set the first time the reference frame is referred to in the command file. Subsequent commands cannot change the type. The only reason for choosing one or other type is to allow reference frame rotations to be defined in one or other system. The output file will list both the topocentric and the geocentric definition regardless of the type.

Topocentric reference frames are calculated using the topocentric axes at the midpoint of the network. This point can be explicitly defined using the “topocentre” command (see above, page 5-7). If this is not done then SNAP will determine the midpoint of the network automatically.

The following example sets the values for the scale and rotation of reference frame parameters of the default reference frame, which has code “GPS”.

```
reference_frame GPS scale -4.6 rotation -0.47 0.10 -1.024
```

The second example calculates a scale and a rotation about the vertical axis, but restrains the tilts (rotations about horizontal axes) to be 0. To do this the reference frame type is geocentric, and a “?” is placed after the third rotation component (which is rotation about the vertical axis).

```
reference_frame topocentric GPS scale 0 ? rotation  0  0  0 ?
```

The final example calculates all parameters for a reference frame with code “GPS2”

```
reference_frame calculate GPS2
```

Adjustment options

Program mode

The program can operate in four basic modes. These are:

- Network analysis: This is used for planning surveys. An artificial set of data is used to see how accurately stations are located. Only the errors of the observations are used - their values are ignored (See “Using SNAP for network preanalysis”, page 2-8).
- Data checking: The input data are compared with the station coordinates as a check for gross errors (such as typing errors) in the data files. Obviously this is only useful if the station coordinates are quite accurate. Even though coordinates are not being calculated SNAP may still be doing a least squares adjustment to calculate parameters such as refraction coefficients, and orientations of horizontal circles. This is effectively the same as fixing all stations.
- Free net adjustment: The input data is adjusted without holding any stations fixed. SNAP generates a minimum set of constraints to adjust the data without compromising the data. This provides a check on the internal consistency of the data. It may be useful to distinguish between gross errors in the data, and errors in the assumed station coordinates.
- Adjustment: This is the normal mode in which station coordinates are adjusted to best fit the observations.

The program can also be constrained to adjust only horizontal or vertical coordinates rather than doing three dimensional adjustment. This is effectively the same as fixing all vertical or horizontal coordinates.

Commands

config **mode *dimension mode***

Defines how the program will operate. The parameters are:

dimension one of "horizontal", "vertical", or "3d".

mode one of "network_analysis", "data_check", "free_net_adjustment", or "adjustment",.

Examples of the mode command are:

mode 3d adjustment

mode horizontal network_analysis

config

convergence_tolerance *value*

value The least squares adjustment iterates until the maximum change to a coordinate is less than this value (in metres). The default value is 0.001 metres.

config

max_iterations *value*

value defines the maximum number of iterations that SNAP will attempt. If the adjustment has not converged after the specified number of iterations it is terminated. SNAP issues a warning error if it fails to converge. The default is 5 iterations.

config

max_adjustment *value*

value Defines the maximum allowable adjustment to a station in metres. If the adjustment to any station exceeds this amount, then SNAP reports an error and the adjustment is terminated. This facility is mainly to avoid unnecessary work if there is a gross error in the data. The default value is 1000 metres.

reorder_stations *option* [except *station_list*]

SNAP may reorder the stations that are being adjusted to minimize the bandwidth of the normal equations (this allows a more efficient adjustment). By default it only does this if there are more than about 50 stations being adjusted. However you can force SNAP to do (or not do) reordering with this command. You can also select stations that will not be involved in the reordering. These stations are put at the end of the normal equations. You would normally do this with stations that are connected by observations to very distant stations. In practice there is rarely any need to modify the default behaviour of SNAP.

option can be one "on", "off". If "on" then the parameters of the adjustment are reordered to minimize the bandwidth of the normal equations. If "off", then the full normal equation matrix is used. By default reordering is done if there are more than 50 stations in the adjustment.

station_list is a list of stations as described above.

config

deformation type=*type* model=*model* epoch=*epoch* [params]

Defines a deformation model that applies for the adjustment. Currently the only type of model supported is a velocity model in which each station has a constant velocity. The velocity model is used to reduce all observations to a common epoch for the adjustment. If a deformation model is defined then every observation must have a defined date of observation.

type The type of deformation model to use. Currently the only valid type is “velocity”.

model Defines the specific model to apply. For the velocity type of deformation model this is the name of a file containing a gridded velocity model in a binary format.

epoch	The date at which to calculate coordinates - this is entered as a decimal year number, eg 1997.5.

Modifying the program output

Commands

title *title text*

Defines the title that will be placed at the top of each page of output. An example would be

title Redefinition of station Arawika

config

list *list_options*
print *list_options*

The list (or print) command specifies which components of the output listing are to be printed, and also provides some control over the format of those sections. *list_options* is a list of sections that can be included in the output. For example the listing can include the adjusted coordinates of the stations. This section is referred to as "station_coordinates" in the list command. So to include this section the command required is

list station_coordinates

If the section is not wanted, it can be excluded by prefixing the station name with "no_". The command to exclude station coordinates is thus

list no_station_coordinates

Several sections can be included in the same list command, each separated by one or more spaces. Here is a more complex list command

list command_file no_file_summary no_station_coordinates

The following section names can be included in the list command. They are described here in the order that they would appear in an output listing file. Sections preceded by a tick (✓) are output by default, whereas those preceded by a cross (✗) are not.

✗command_file	Puts a copy of the input command file into the output listing. Note that this does not list included command files or configuration files that also affect the adjustment.
✓file_summary	Lists the input data files used in the adjustment. The listing describes the number of each type of observation that have been read from each file.
✗input_data	Makes a detailed list of the input data. The format of the data is not very readable. This is intended for debugging the program more than for use in interpreting the adjustment.
✗problem_definition	Summarizes the adjustment that will be done. This section lists the stations that will be adjusted or fixed and the additional parameters that will be calculated in the adjustment.
✓iteration_summary	Prints a summary of each iteration which lists the maximum change to a station coordinate.
✗observation_equations	Prints a list of the least squares observation equations at each iteration. This is intended for debugging purposes only.

✗station_adjustments	Prints a list of all adjustments to station coordinates at each iteration.
✓solution_summary	Summarizes the statistics of the solution (number of observations, number of parameters, degrees of freedom, and so on).
✓station_coordinates	Prints a list of station coordinates, total adjustments to the coordinates, error ellipses, and height errors.
✓floated_stations	Prints a list of adjustments of floated stations with their significance.
✓reference_frames	Prints a list of reference frames used by GPS data.
✓parameters	Prints a list of additional parameters of the adjustment with their values and errors.
✓residuals	Prints a list of all observations used. By default this includes the residuals errors and standardized residuals for each observation. However the contents of this section can be changed with the "define_residual_format" and "add_residual_column" commands.
✓error_summary	This section presents accumulated error summaries. By default it presents summaries of the errors for each data file and for each data type. However you can obtain other summaries using the "summarize_errors_by" command.
✓worst_residuals	Prints a list of the worst standardized residual errors in the adjustment. By default the 10 worst residuals are listed. This can be modified with the "number_of_worst_residuals" command.

The list and print command are also used to modify the presentation of some sections of the output. The following items can be included as list options. Again the options are turned off by prefixing them with "no_".

✓notes	Specifies that notes associated with observations (using #note in the data file) will be copied to the list of residuals.
✓rejected_stations	Specifies that rejected stations will be included in the output. If rejection stations are excluded (using "list no_rejected_stations") then rejected stations and observations to them are omitted from the output. This causes rejected stations to be treated the same way as ignored stations.
✗grouped_data_by_type	By default observations are listed in the same order as they occur in the input. If this option is selected then grouped data involving more than one data type are listed showing each type separately. This is often a lot clearer. For example if the input contained grouped data with a horizontal angle and a slope distance on each line. then the output would contain all the distances for the each set followed by all the angles.
✗sort_stations	By default stations are listed in the listing file in the same order that they appear in the input coordinate file. Using this option causes them to be sorted according to the station code.
✓form_feeds	By default sections in the output file are separated by form feed characters. These can be suppressed using the no_form_feeds option.

config

output *output_options*

The output command is used to control output of the files other than the listing file. Its syntax is very similar to that for the list command - it may be followed by several options separated by spaces. Each option can be negated by preceding it with “no_”. The options that are available with the output command are:

✓binary_file	Creates a binary file which is used by SNAPPLOT and other programs to obtain information about the adjustment for subsequent display and processing.
✓coordinate_file	Creates a new version of the station coordinate file.
✓rejected_station_coordinates	By default rejected and ignored stations are copied into the new coordinate file. The can be omitted by using the “no_rejected_station_coordinates” option.
×covariance_matrix_file	Creates a text file listing the covariance matrix of the derived coordinates. This may be used as input to other programs.

config

define_residual_format *type fields*
add_residual_column *type fields*

These commands are used to modify the layout of the listing of observation residuals. They are discussed more fully below (see “Modifying the residual listing”, page 5-19).

config

output_precision *type precision type precision ...*

This command is used to change the numerical precision of the output data. For example slope distance data are usually printed to four decimal places. This can be changed to 3 decimal places with the command

```
output_precision  sd  3
```

The parameters of this command are:

type	A data type as defined above for data files. For example “HA” for horizontal angles.
precision	The number of decimal places to display for observations of the preceding type. This must be between 0 and 9 inclusive.

config

coordinate_precision *precision*

This defines the number of decimal places used to print coordinates in the listing file. It affects projection coordinates only. The command is ignored for geodetic (latitude/longitude) coordinates. The parameter of the command is:

precision	The number of decimal places used.

config

sort_observations *[option]*

By default observations are listed in the output file in the same order as they occur in the input file (except that grouped data may be reordered with the “list grouped_data_by_type command). The sort_observations command can be used to obtain different orderings. The possible values for *option* are:

by_line	Observations are sorted according to the line measured. Observations between each pair of stations are grouped together regardless of which direction the observation was made. For example a distance measurement from station 01 to station 02 will be listed with measurements from 02 to 01. For observation types where the instrument and target are not interchangeable (for

example horizontal angles) only the instrument station is used for sorting.

by_instrument_station	Observations are sorted first by the instrument station, then by the target station In this case a distance from 02 to 01 will be listed with other observations from 02, not with observations from 01 to 02.
by_type	Observations are sorted by the type of observation. In this case all the distances are listed first, then the angles, and so on.

If the sort_observations is used without a parameter then observations are sorted by line.

config

station_code_width *number*

Specifies the number of characters to allocate for station codes in the output listing. The default is 5, or the length of the longest code, whichever is greater.

number	The number of columns used for printing station codes in the listing file. The maximum is 10.

config

file_location_frequency *number*

In the residual listing SNAP includes information about the name of the input data file and the line number in the file from which observations have been read. This is to facilitate checking and editing the data file. To avoid cluttering the output listing this is only done after about every 20 observations. The frequency of this information can be changed with the file location frequency command. The parameter of the command is:

number	Specifies the frequency with which information about the source of data is included in the list of residuals. Use 0 to suppress file location information. If observations are sorted (with the “sort_observations” command) then the frequency must be 0 or 1.

config

number_of_worst_residuals *number*

At the end of the listing file SNAP prints a list of the observations with the most significant residuals. By default SNAP lists the 10 worst residuals. You can use this command to list more or less residuals.

number	Specifies how many of the worst residuals are listed.

config

flag_significance [maximum] *value1* [maximum] *value2*

In the list of residual errors SNAP flags the observations which have excessive residuals. There are two thresholds which control this flagging. Residuals for which the statistical significance exceeds the first threshold (*value1*) are indicated by “?” in the listing. Residuals which exceed the second (*value2*) are identified by “???”.

Each threshold can be entered as either a percentage (e.g. “95”), or as “maximum” followed by a percentage.

Entering just the percentage will flag residuals that specified significance within the individual adjustment. For example if the threshold is set at 95%, you would expect 5% of observations in an adjustment to exceed it.

Entering “maximum” and a number will flag residuals that exceed the maximum residual that would be expected in the specified percentage of adjustments. That is, if you enter the threshold as “maximum 95”, then you would only expect an observation to be flagged in 5% of all adjustments.

The default flag levels are 95% and 99% .   A good alternative would be to use the following command:

flag_significance 95 maximum 95

config

redundancy_flag_level *level*

In the residual listing SNAP prints an "@" by observations for which there is little redundancy. These are observations which only weakly checked by the other observations and fixed station coordinates.   They indicate a deficiency in the network design. The redundancy is expressed by a number between 0 and 1, where 0 indicates no redundancy (the observation is unchecked) and 1 indicates perfect redundancy.   The parameter of this command is:

level — Defines the redundancy level below which observations are flagged as having low redundancy. The default is 0.1.

config

mde_power *power*

One additional column that can be included on the residual listing is the marginal detectable error (MDE). This is smallest error that will be flagged with a given confidence. The confidence that a bad observation will be flagged is termed the power of the test. The mde_power command defines this power. For example if the flag significance level (for the ?flag) is 95% and the MDE power is 80%, then the value that will be shown for an observation is the smallest error that there would need to be in the observation in order to be 80% confident that it would be flagged at the 95% significance level.

power — Defines the power for which the marginal detectable error is calculated as a percentage.

config

summarize_errors_by *definition definition ...*

The error summary in the listing file presents error statistics compiled for groups of observations. The groups defined by observation classifications including the default classifications "data_file" and "data_type".

The "summarize_errors_by" command is followed by one or more summary definitions. Each definition consists of one or more classifications separated by the slash character "/".

The default output is created by the command

summarize_errors_by data_type data_file

This creates two separate error summaries. The first shows the statistics accumulated for each data type, and the second the statistics for each data file.

If the command were changed to

summarize_errors_by data_file/data_type

then the listing would show the statistics for each data file, and accumulations for each data type *within* each data file.

config

error_type *type*

This command specifies how errors are to be represented in the listings. The parameter is:

type — can be "apriori" or "aposteriori"

"apriori" errors are calculated purely in terms of the errors specified in the input data. They take no account of how well the data fit together with the fixed stations. "aposteriori" errors are scaled to reflect the quality of fit of the data.

Generally apriori errors are more appropriate where there is little redundancy in the data, or where the quality of the observations is well known from previous surveys or tests. If there is little redundancy then there are not enough “spare observations” to determine the quality of fit of the data.

Aposteriori errors are better suited when the quality of the data is uncertain and there is good redundancy in the observations.

Modifying the residual listing

The listing of residuals is generally the most important component of the output. In SNAP you can choose what information you want in that listing and how it is to be laid out. You can also specify the numeric precision of the data. The commands to do this are “define_residual_format”, “add_residual_column”, and “output_precision”.

The “define_residual_format” and “add_residual_column” commands define the columns that will be output for each data type. “define_residual_format” creates an entirely new format, whereas “add_residual_column” extends the existing formats. The syntax for these two commands is identical:

define_residual_format *data_types columns*
add_residual_column *data_types columns*

In these commands *data_types* specifies the data types for which the format applies. This can be any of the data type codes (e.g. HA, SD, GB), or it can be ALL (all data types), POINT (point data types - latitude and longitude), LINE (line data types such as angles and distances), or VECTOR (vector data types, currently only GPS). You can also combine several data types separating them with a “/” character, e.g. ED/SD/HD.

The *columns* parameter specifies the data to be output in the residual listing. Each column in the output is specified by a string of the form

field_name:width:title1:title2

Here *field* is the name of the field to output (see table below), *width* is the number of characters allowed for the field in the residual listing, and *title1* and *title2* are the titles used to head the output columns. The width and titles do not need to be specified - SNAP will choose defaults for these.

The column definition cannot include any blank characters. To put a blank into the title use an underscore character in the definition. If you need an underscore, colon, or backslash in the title then these must be preceded by a backslash in the definition. As a rather contrived example, the definition

from:12:Obs_station\::\\code_name

would create a column 12 characters wide listing the instrument station codes and headed

Obs station:
\code_name

By default a single blank character is inserted between each output field. If you want to insert extra space, you can do this with the field specification S:n, where n is the number of spaces to leave. You can also spread the information over more than one line by using the “NL” field specification to start a new line.

Here is an example of a simple residual listing format:

define_residual_format line from to type res_val res_err alt_res std_res flags

The add_residual_column command can be used to add a column to the default format, or to build up the format where it cannot easily be represented on just one line of the command file. (That is, you can start a format with the define_residual_format command, and add each column with the add_residual_column command).

An example of this command to add part per million residuals to distance observations would be add_residual_column   sd/hd/ed   alt_res:8:ppm:residual

The "output_precision" command specifies the number of decimal places used to output each type of data. It is followed by a series of data types and numeric precisions. For example you could specify

output_precision SD 4 ED 4 HD 4 HA 2 AZ 2

Field name	Contents
from	Station code of the instrument station
to	Station code of the target station
from_name	Station name of the instrument station
to_name	Station name of the target station
hgt_inst	Height of the instrument
hgt_trgt	Height of the target
type	Code for the type of observation (e.g. SD, HA...)
file	Name of the source data file
file_no	Number of the source data file
line_no	Line number of the observation in the data file
obs_val	Observed value
obs_err	Error of the observed value
calc_val	Calculated value
calc_err	Error of the calculated value
res_val	Residual
res_err	Error of the residual
alt_res	Alternative representation of the residual①
std_res	Standardized residual
redundancy	Redundancy factor of the observation
mde	Marginal detectable error
flags	Significant residual and rejected observation flags
azimuth	Azimuth of the line
prj_azimuth	Projection azimuth (blank for geodetic coordinate files)
hgt_diff	Height difference on the line
arc_dist	Ellipsoidal arc distance of the line
slp_dist	Slope distance of the line
C=xxxx	The xxxx classification of the observation
S	a blank space
NL	start a new line

① The alternative representation of the residual (alt_res) depends upon the data type. For distances, height differences, and GPS baselines it gives the error in part per million of the line length. For horizontal angles and azimuths it the equivalent horizontal offset perpendicular to the line. For zenith distances it is the equivalent error in the height difference.

Testing relative accuracy specifications

SNAP can be used to test that adjustments achieve a specified relative accuracy in the calculated coordinates of the stations. The accuracy is defined in terms of horizontal and vertical components of accuracy, each of which comprises an absolute (mm) and a distance dependent (ppm) tolerance. Every calculated vector between a selected list of stations is tested against this accuracy. More than one specification can be defined, with different sets of stations being tested against each specification.

Note that if these tests are being applied the bandwidth optimisation the full covariance matrix of the coordinates is required to calculate all vectors, so that the inversion of the normal equations may take longer than normal.

Commands

config

specification *name* confidence *conf* % [horizontal *habs* mm *hppm* ppm *hmax* mm_abs] [vertical *vabs* mm *vppm* ppm *vmax* mm_abs]

Defines an accuracy specification. Each specification is named (eg order1). The name is used to specify which stations it applies to with the test_specification command. The specification can define horizontal and/or vertical absolute and relative accuracy tolerances.

The parameters of the command are:

name	The name used to refer to the specification.
conf	The percentage confidence to use for the test
habs	The absolute component of the horizontal tolerance in millimetres
hppm	The distance dependent component of the horizontal tolerance in part per million.
hmax	The maximum horizontal absolute error of a coordinate in millimetres
vabs	The absolute component of the vertical tolerance in mm.
vppm	The distance dependent component of the vertical tolerance in part per million.
vmax	The maximum vertical absolute error of a coordinate

An example of this command would be:

```
specification order_2 confidence 95% horizontal 3mm 1ppm
50mm_abs vertical 10mm 3ppm 150mm_abs
```

config **spec_test_options *options***

Specifies the options that apply for the specifications test. The options that can be included are:

apriori	A priori errors will be used (the default)
aposteriori	A posteriori errors will be used
list_all	List all tested vectors individually
list_fail	List all vectors which fail the tolerance tests
list_none	Only print the summary information from the specifications test (the default).

test_specification *name station_list*

Specifies the options that apply for the specifications test. The options that can be included are:

name	The name of the specification to test (as defined in a specification command)
station_list	The list of stations for which to apply the station. This is in the format of a station list as defined above (page 5-6).

An example of this command would be:

```
test_specification order_2  @2ndorder.lst
```

where 2ndorder.lst is a file containing a list of stations which must meet the order 2 specification.

Miscellaneous commands

Commands

configuration *file_name*

This command specifies the name of a configuration file to use for the adjustment. The configuration file is described in more detail above (see “What is a configuration file”, page 5-1). It is used for including groups of options which may apply to many adjustments. For example the configuration file could include a set of commands to get the preferred output format. The parameter of the command is:

file_name	specifies the name of a file from which additional configuration items will be read.

SNAP will look in the following directories in order to locate the configuration file:

- the same directory as the command file
- the user's directory. This directory is defined using either the SNAPDIR environment variable, or the -u option on the SNAP command line
- the same directory as the SNAP program.

include *file_name*

This reads additional commands from another file. The include command differs from the configuration command in that the included command file can include any command (not just configuration commands), and in that it only looks in the command file directory for the included file. It is intended for items that may be common to a number of adjustments working with the same data. For example it could include a list of data files.

file_name	specifies the name of a file from which additional commands items will be read. This can be used for information common to a group of adjustments. For example a set of data files can be defined in an include file.

plot ....

This command is not used by SNAP. It is used to insert instructions for SNAPPLOT into the SNAP command file.

Chapter Six: Output files

The error file

If SNAP encounters any problems doing an adjustment it will report them in an error file. This is put in the same directory as the command file with the same name, but with extension ".ERR". For example, if the command file is "MYJOB.SNP" then the error file will be "MYJOB.ERR".

The error file may describe one or more errors. If the errors are due to syntax errors in the data or command files then SNAP specifies the name of the file, and the line number at which the error was detected.

Some of the more common errors that may occur are described in section "Common problems" (page 2-9). Data file syntax errors are described in "Troubleshooting data file errors" (page 4-18).

The listing file

The listing file is the main output file generated by SNAP. It lists information about the input data, the adjustment, the new coordinates, and the residuals and statistics of the observations.

The listing file is put in the same directory as the command file, and has the same name, but with extension ".LST".

Layout of the listing file

The listing file consists of several sections. Not all sections will be printed in all listing files. The sections that are included depend upon the options selected in the command and configuration files (see the "list" command, page 5-14). The sections that may be present are:

- Summary of input files: a list of the input files. For data files it also show the number of each type of observation that has been read.
- Definition of problem: a list of the parameters (station coordinates and others) that will be adjusted . This section is not printed by default.
- Iteration number #: for each iteration lists the adjustment to the coordinates of each station. This section is not printed by default.
- Iteration summary: contains a summary of the iterations showing the maximum adjustment to a station coordinates. This indicates how rapidly the problem converged.

- Solution summary: lists brief statistics of the adjustment as a whole. This includes the number of parameters, the number of observations, the sum of squared residuals, and the standard error of unit weight.
- Station coordinates: lists for each station the final coordinates, the adjustment done to the coordinates, and the horizontal error ellipse and the height error.
- Floated stations: lists the floated stations in the adjustment together with the amount of adjustment and the standardised residuals for the station coordinate observations.
- Reference frame parameters: lists the scale and rotations applied for each GPS reference frame.
- Other parameters: lists additional parameters of the adjustment such as refraction coefficients, distance scale errors, and so on.
- Observation residuals: for each observation lists the observed and calculated value and the residual error. Observations with unusually large residuals are highlighted..
- Error summary: provides summary statistics for residuals from groups of observations. By default the summaries are presented for observations in each data file, and for each type of observation.
- Most significant residuals: Shows the most significant residual errors in the adjustment.

Each of these sections is described in more detail below.

For most adjustments you will want to check first the iteration and solution summaries - near the top - to ensure that the adjustment has converged properly and that the standard error of unit weight is sensible. Then you will want to review the most significant residuals at the end of the listing. If there are no obviously bad observations then you can review the station coordinates, adjustments, and error ellipses. These are viewed more easily by using the SNAPPLOT program than by reading the listing file.

There are two other sections that can be printed in the listing file. These are:

- Input data: lists the input data.
- Observation equations: for each iteration lists the observation equations.

These sections are mainly intended for debugging purposes. The output is somewhat cryptic and is not described any further in this document.

Apriori and aposteriori errors

Most sections of the output listing include estimates of the errors of the derived quantities. These can be either aprior errors or aposteriori errors. This is controlled by the "error_type" command (page 5-18) in the command or configuration file.

Apriori errors are calculated purely in terms of the errors specified in the input data. They take no account of how well the data fit together with the fixed stations. Aposteriori errors are scaled to reflect the quality of fit of the data. The aposteriori error of a quantity is equal to the apriori error multiplied by the standard error of unit weight.

Generally apriori errors are more appropriate where there is little redundancy in the data, or where the quality of the observations is well known from previous surveys or tests. If there is little redundancy then there are not enough "spare observations" to determine the quality of fit of the data.

Aposteriori errors are better suited when the quality of the data is uncertain and there is good redundancy in the observations.

The choice of apriori or aposteriori errors also affects the way in which the significance of residuals are estimated as the probability distribution of apriori and aposteriori residuals are different.

The summary of input files section

Here is an example of the summary of input files section.

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            12-JUN-1995 11:13:20

                             SUMMARY OF INPUT FILES

================================================================================

Program options read from demo.cmd

Job: SNAP demonstration - locate 14361 and Mt Stewart

Solution type: 3d coordinate adjustment

Coordinates file demonzmg.crd
       5 stations read

Data file 1: demogps.dat
        Errors multiplied by 2.00
       3 GPS baselines

Data file 2: demo.dat
       5 slope distances
       6 horizontal angles

Data file 3: demopt.dat
       2 latitudes
       1 longitude
```

The problem definition section

The problem definition section summarizes the parameters that are being calculated. It also lists which station are floated (if any), and which stations have been rejected. This section is printed if the command or configuration files include the command "list problem_definition".

Here is an example of a problem definition file.

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            12-JUN-1995 11:13:20

                             DEFINITION OF PROBLEM

================================================================================

Solution type: 3d coordinate adjustment

The following table lists the stations included in the adjustment.
Adjustment is signified by F (fixed), H (horizontal), V (vertical) or 3 (3d).

Station  Adj  Name

1        F   AHIWEKA
2        F   34 TE AWAPUTAHI
3        F   B ROSS
4        3   14361

The following stations have been rejected.  Those denoted with '*'
have been rejected automatically because there is insufficient data
to locate them.

Station  Name

*5       MT STEWART❶

The following parameters are also being calculated

GPS rotn Z (sec)
GPS X shift (m)
GPS Y shift (m)
GPS Z shift (m)GPS Z rotn (sec)
```

❶ In this example station 5 was automatically rejected from the adjustment because there were only two observations to the station. This was not enough to fix the station in a three-dimensional adjustment.

The iteration summary

SNAP can record information about each iteration in the listing file. By default this is a short section which lists the maximum adjustment to a station at each iteration. If the command or configuration files include the command “list station_adjustments” then a separate section is printed for each iteration which lists the adjustment of every station.

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            26-NOV-1992 07:50:01

                               ITERATION NUMBER 1

================================================================================

Changes to station coordinates

Code      East      North       Up       Name

4         0.1058     0.0739      -       14361
5         0.0417     0.0683      -       MT STEWART

Iteration 1: Maximum change is 0.1291 metres at station 4
```

The solution summary

The solution summary briefly describes the result of the adjustment. You should always check this section to see how the residuals compared with your expected errors. The two main items to note from this section are:

- the standard error of unit weight. This indicates how well the residual errors on the observations compare with the expected errors specified for the data in the input files. If this is significantly greater than one then it implies that the residuals are larger than expected. This may indicate a gross error in the data, or an error in the fixed station coordinates, or that the errors in the input files have been underestimated. If it is significantly less than one it suggests that the errors in the input file have been overestimated.
- the degrees of freedom. This indicates how much overall redundancy there is in the network. A low value for the degrees of freedom implies that the aposteriori statistics (those based upon the standard error of unit weight) may not be very reliable.

Here is an example of a solution summary:

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            26-NOV-1992 07:50:01

                                SOLUTION SUMMARY

================================================================================

Solution type: Horizontal coordinate adjustment

Number of observations:             22
Number of parameters:                8
Number of implicit parameters:       2 ❶

Degrees of freedom:                 12
Sum of squared residuals:           10.68415
Standard error of unit weight:       0.94358

The probability of an SSR this low is 44.384% ❷
```

❶ Implicit parameters are parameters which are adjusted in principle, but for which observations equations are not actually formed. These include the orientation of the horizontal circle for horizontal angles, and the scale error for sets of distance ration data. These parameters are eliminated in SNAP using Schreiber's method.

❷ SNAP indicates the probability of obtaining standard errors of unit weight as extreme as that obtained by a probability percentage. This probability is based upon the errors specified for the data.

This probability can be misleading. For a large adjustment the standard error of unit weight may be 0.99 (that is, very close to the "correct" value of 1.0), and yet SNAP will report that the probability of a value this low is 0%.

The reason this occurs is that this error takes into account the specified errors of the observations, but not the errors of the errors. If we specify the expected error of an angle observation is 1 second then SNAP takes this as being exactly correct. In practice we cannot know the error of our observations precisely. In a large adjustment with many redundant observations the standard error of unit weight is determined very precisely in relation to the observation errors. Given the specified input errors it may be derived as 0.990 ± 0.001. This is 10 standard deviations from the "correct" value, which is very unlikely. SNAP will conclude that we must have overestimated the errors (by 1%). If SNAP could take account of the uncertainty of the errors we specified then it would obtain a more realistic error for the standard error of unit weight, say 0.990 ± 0.3, and would not indicate a problem with the adjustment.

The station coordinates section

The station coordinates section lists the stations, the changes to their coordinates, and the error ellipse and/or height errors of the derived positions.

Often it is more useful to use the program SNAPPLOT to display adjustments and error ellipses rather than reading the coordinate listing.

The coordinates will be listed in the same system as the input coordinates (i.e. if the input coordinates are on the NZMG projection, then that projection will be used in the listing file). The only exception is that if the input file is expressed in geocentric cartesian coordinates the listing will show the coordinates in latitude and longitude.

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            26-NOV-1992 07:50:01

                              STATION COORDINATES

================================================================================
Coordinate system: New Zealand Map Grid
Ellipsoid: International ellipsoid
   a = 6378388.000  1/f = 297.000000
Projection: New Zealand Map Grid
The error ellipse and height error represent the aposteriori errors

Rejected stations are flagged #

 Code       Latitude       Adjustment  Error  Brng  Name
            Longitude       (metres)  Ellipse
            Height                    Hgt err

 3      2711191.8432      -         - ❶          B ROSS
        5998837.0638      -         -
           1053.1100      -         -

 4      2732472.7631     0.1026❷  0.0370  29❸  14361
        5999578.4420     0.0674    0.0222 119
            143.1564    -0.1336    0.2430
```

❶ No adjustment or errors are shown for station 3 because it is fixed in the adjustment.

❷ The adjustment shows the total change to the station coordinates for all iterations. It is always expressed in metres, even if the coordinates are latitude and longitude.

❸ The horizontal errors are represented by an error ellipse - not by the individual errors in the north and east directions. In this case the error ellipse has an axis 0.0370 metres long oriented N29°E and an axis 0.0222 metres long oriented at N119°E. The height error is 0.243 metres.

The floated station section

The floated station section lists any floated stations in the adjustment. It is only printed if there are floating stations. This sections shows the adjustment of the floating station and the standardised residual for the station coordinate observations that SNAP creates for floated stations.

Here is an example of the floated stations section of the listing file:

```
================================================================================
SNAP test adjustment                                        21-JUN-1995 11:01:54

                                FLOATED STATIONS

================================================================================

This list shows aposteriori errors

Adjustments outside the 95.000% confidence limit are flagged ?
Adjustments outside the 99.000% confidence limit are flagged ???
Significance is based on the Tau distribution with 54 degrees of freedom

Code    coord      error      calc.err  adjustment    adj.err    std.res

3       East       0.6637      0.2606      0.2164      0.6104     0.3545
        North      0.6637      0.2241     27.5686      0.6248    44.1256 ???
        Up         0.6637      0.6637      0.0000      0.0000     1.0891

83      Up         0.6637      0.2794      0.4532      0.6021     0.7527
```

For floated stations the input coordinates are treated as observations rather than as constraints. This listing shows the expected error of each coordinate, the calculated error of the coordinate after adjustment, the amount of adjustment to the coordinate (which is the residual of the observation), the error of the adjustment as a residual, and the standardised residual of the observation.

The reference frame section

The reference frame section describes any GPS reference frames that have been used in the adjustment. It is only printed if the adjustment includes GPS data.

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            12-JUN-1995 11:13:20

                           REFERENCE FRAME PARAMETERS

================================================================================

The errors listed for calculated parameters are aposteriori errors

Topocentric axes are east, north, up directions at ❶
    41 12 34.60588S    175 35 01.73369E

Reference frame: GPS

   Calculated as a geocentric reference frame ❷
```

```
  Geocentric definition

     Parameter                          Value      Error
     X rotation (arc sec)              -0.4247      0.7480
     Y rotation (arc sec)               1.8753      3.9557
     Z rotation (arc sec)               0.4992      1.1151
     Scale factor (ppm)                -0.0824      0.8184

     Correlation matrix:
         1.0000
        -0.8467    1.0000
        -0.9040    0.9203    1.0000
        -0.1097    0.0097   -0.0611    1.0000

  Topocentric definition ❶

     Parameter                          Value      Error
     East rotation (arc sec)           -1.8370      3.8953
     North rotation (arc sec)           0.7496      1.4857
     Vertical rotation (arc sec)        0.0983      0.2638
     Scale factor (ppm)                -0.0824      0.8184

     Correlation matrix:
         1.0000
        -0.9322    1.0000
        -0.1025    0.0929    1.0000
        -0.0082    0.0031    0.4120    1.0000

  Minimum error of horizontal tilt is 0.50602 arc sec ❸
  Maximum error of horizontal tilt is 4.13818 arc sec
  Rotation axis of maximum tilt error has azimuth 110 degrees
```

❶ The topocentric rotations are defined in terms of the east, north, and up axes at a point in the centre of the network. This point can be specified with the “topocentre” command in the command file. If it is not specified SNAP determines a point in the centre of the network to use.

❷ Each reference frame can be calculated in terms of geocentric or topocentric rotations. Whichever is used, both definitions are listed in the output file.

❸ SNAP indicates the axes on which the error of the horizontal tilt is maximum and minimum (note that this is not the same as the axes about which the tilt itself is maximum or minimum). This may be useful to identify configuration problems in the vertical control points. In this case there is a large difference between the minimum and maximum tilt errors which indicates that the vertical control is badly configured. The maximum tilt error occurs with a rotation axis at azimuth N110°E. To remedy this would require a better spread of vertical control points perpendicular to this axis.

The parameters section

This section lists the additional parameters involved in the adjustment. These parameters may include refraction coefficients, distance scale errors, bearing orientation errors, and a reference frame scale error.

Here is an example showing additional parameters for an adjustment which involved several different values for the refraction coefficient.

```
================================================================================
SNAP parameter test                                         21-APR-1995 09:17:16

                                OTHER PARAMETERS

================================================================================

The errors listed for calculated parameters are apriori errors

Parameter                          value         +/-

Refr coef DEFAULT                    0.00000       - ❶

Refr coef RC1                       -0.00235      0.03921
```

```
Refr coef RC2                           0.09068      0.02682

Refr coef RC3                           0.09068      0.02682  = Refr coef RC2 ❷

Refr coef RC4                           0.08000       -
```

❶ No errors are specified for refraction coefficients DEFAULT and RC4. This is because the values were defined in the configuration file, not calculated.

❷ Refraction coefficients RC2 and RC3 have been forced to have the same value in the adjustment.

The observation residuals section

The observation residuals section lists the individual observations used in the adjustment. You have a lot of control over what gets printed in this section (see "Modifying the residual listing", page 5-19).

Generally this section lists the observed and calculated values for each observation and the residual error. Note that all calculated values listed by SNAP are calculated to be comparable with the observed values. This means that slope distances are calculated including the instrument and target height and distance scale errors, zenith distances are calculated including refraction coefficients, and so on.

The residual errors may be presented in a number of ways. By default SNAP shows the difference between the observed and calculated values (except for GPS data, see below) and standardized residuals. You can choose to also list the residual in an alternative form which depends upon the data type. For example, for distance measurements this will be a part per million error and for zenith distances this will be a height difference.

The main reason for reviewing the observation residuals is to identify possible gross errors in the data. SNAP assists this by putting "?" and "???" flags by observations with large standardized residuals. You choose the significance level at which these are printed with the "flag_significance" command (page 5-17) in a command or configuration file. SNAP also lists the most significant residuals at the end of the listing file in the "most significant residuals" section (page 6-10).

SNAP flags observations having poor redundancy with "@". These observations are not well checked by the other data and station coordinates. Ideally they should be supported by extra observations, though of course this is not always practical.

When assessing the residuals keep in mind that one effect of least squares is to distribute the error among the observations. If one observation is corrupted by a gross error then it may cause a large number of observations to be flagged. Also remember that bad residuals may be caused by incorrect coordinates of fixed station as well as by errors in the data.

Here is an example of a listing of observation residuals:

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart            13-JUN-1995 08:57:28

                             OBSERVATION RESIDUALS

================================================================================


This table lists aposteriori errors
Residuals outside the 95.000% confidence limit are flagged ?
Residuals outside the 95.000% confidence limit for the maximum are flagged ???
Significance is based on the Tau distribution with 11 degrees of freedom
(the Students t distribution is used for rejected observations)

Rejected observations are flagged *
Observations to or from rejected stations are flagged #
Observations with redundancy less than 0.10 are flagged @

Vector residual east, north, up directions are calculated at
    41 12 34.60588S    175 35 01.73369E
```

```
The following codes are used to identify data types
   SD  slope distances
   HA  horizontal angles
   GB  GPS baselines
   LT  latitudes
   LN  longitudes
Note: Calculated values for slope distances include equipment heights

From  To    Type    Value     +/-      Calc      +/-     Res    +/-    S.R.
                    X,Y,Z              X,Y,Z            E,N,U

File demogps.dat: line 11 ❶

1     2     GB      -399.320  0.082    -399.288  0.072  -0.030  0.024   1.20 ❷
                   20958.800  0.030   20958.767  0.018   0.048  0.051   0.92
                    2497.100  0.078    2497.066  0.070   0.004  0.013   0.29
                   21110.809          21110.772          0.057          0.95


From  To    Type    Value     +/-      Calc      +/-     Res    +/-    S.R.

File demo.dat: line 18

1     2     HA     0 00 00.0    1.9 359 59 59.8    1.3     0.2    1.4   0.16
      3     HA    15 23 16.8    4.9  15 23 18.0    1.3    -1.2    4.7   0.26
      4     HA    48 58 07.2    1.9  48 58 07.2    1.3     0.0    1.4   0.02

4     3     SD    21314.2180 0.0426  21314.1802 0.0268  0.0378 0.0331   1.14
      5     SD#   14296.9110 0.0294  14296.8694 0.0284  0.0416 0.0409   1.02 # ❸

Distance to station 1 is suspect - low signal strength ❹
      1     SD*   17969.4340 0.0363  17967.4405 0.0253  1.9935 0.0442  45.06 *???❺
```

❶ SNAP prints the source file name and the line number for the input data at intervals throughout the output file listing. This is to facilitate relating observations in the output to those in the input file. The frequency of these notes is controlled by the “file_location_frequency” command in the listing or configuration files (page 5-17).

❷ GPS observations are represented by four lines of output. For the observed and calculated values these show the X, Y, and Z components of the vector and the length of the vector. For the residual these show the east, north and up components and the length of the residual vector. Note that the length of the residual vector is not the same as the difference between the calculated and observed lengths. For the standardized residual these show the east, north, and up standardized residual, and a “vector standardized residual” (which indicates the overall significance of the vector residual).

The listing does not show the correlations between the components of the vector, nor that between vectors for multistation GPS data.

The east, north, and up directions may be calculated once at the topocentre of the network, or may be calculated individually for each line. This is controlled by the “gps_vertical” command (page 5-9). The topocentre of the network may be defined by the “topocentre” command (page 5-7).

❸ Observations to and from rejected stations are listed in the output file unless the “list no_rejected_stations” command is specified in a command or configuration file. Observations relating to ignored stations are not listed.

❹ Notes associated with observations (using #note in the data file, see page 4-14) are copied to the output file by default. They can be omitted using the “list no_notes” command.

❺ In this adjustment the distance from station 4 to station 1 was rejected in the data file (indicated by the asterisk “*”). SNAP still shows the residual and has flagged it as significant with the “???” annotation.

The residual summary section

The residual summary section provides accumulated statistics (root mean square of standardized residuals) for various groups of observations. This may be useful for identifying inappropriate weighting for input data. For example if on average the standardized residuals of distance data are twice as large as those of horizontal angle data, then you may choose to increase the errors specified the distance data and redo the adjustment.

The contents of the error summary section is controlled by the “summarize_errors_by” command (page 5-18).

For each group of data SNAP calculates the root mean square standardized residuals of the used observations, of the unused observation (either rejected observations or observations between rejected stations), and of all observations.

Note that you should not place much significance on statistics which are derived from only a few observations.

Here is an example of an error summary section:

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart           13-JUN-1995 08:57:28

                                 ERROR SUMMARY

================================================================================

Summary of residuals classified by data type

Classification                               Used        Unused       Total
                                            RMS  Count   RMS  Count   RMS  Count

slope distance                              1.17    3   31.87    2   20.18    5

horizontal angle                            0.16    5    0.35    1    0.20    6

GPS baseline                                0.93    9     -      -    0.93    9
        East component                      0.87    3     -      -    0.87    3
        North component                     1.07    3     -      -    1.07    3
        Up component                        1.19    3     -      -    1.19    3
```

The most significant residuals section

SNAP can summarize the residuals in a separate section. This section contains counts of the residuals classified according to their significance, and a list of the worst residuals. By default it lists the 10 observations with the most significant residuals. You can choose to list a different number of observations with the “number_of_worst_residuals” command in the command or configuration file (page 5-17).

The residuals in this list are identified by the name and line number of the data in the source data file.

```
================================================================================
SNAP demonstration - locate 14361 and Mt Stewart           13-JUN-1995 08:57:28

                           MOST SIGNIFICANT RESIDUALS

================================================================================

The 17 residuals from this data are classified as follows:

Under 95.00%  significant    Used:  13    Unused:   2
Under 95.00%M significant    Used:   1    Unused:   0
Over  95.00%M significant    Used:   0    Unused:   1

The 'M'indicates that the significance applies to the maximum
of all residuals rather than to the individual residuals.
Note: Only the overall residual for vector data is counted
```

```
The following table lists the 3 worst residuals of rejected data ❶

From   To     Type     S.R.  Sig (%)       Line  File

Distance to station 1 is suspect - low signal strength ❷

4      1       SD*   45.064  100.000 ???     27  demo.dat
4      5       SD#    1.018   66.936         24  demo.dat
4      5       HA#    0.351   26.760         24  demo.dat


The following table lists the 10 worst residuals of used data

From   To     Type     S.R.  Sig (%)       Line  File

3              LT     2.195   98.090 ❸      12  demopt.dat ❹
1      4       SD     1.500   86.019         20  demo.dat
4      3       SD     1.142   72.698         23  demo.dat
1      4       GB     1.067   63.054         13  demogps.dat
1      2       SD     0.719   50.121         18  demo.dat
1      2       GB     0.946   50.005         11  demogps.dat
3              LN     0.585   41.673         12  demopt.dat
1      3       GB     0.760   30.639         12  demogps.dat
1              LT     0.408   29.671         11  demopt.dat
1      3       HA     0.264   19.453         19  demo.dat
```

❶ The rejected and used observations are listed separately. In this case there were only 3 rejected observations. (By default SNAP will list up to 10 values). The data type column includes flags indicating why the observations has been rejected. These are the same in the observation residuals section: "*" indicates that the observation has been explicitly rejected and "#" indicates that it involves a station that has been rejected.

❷ Notes attached to observations with the #note data specification command in a data file are copied to the worst residuals section. They are not printed if the command or configuration files includes a command "list no_notes"

❸ The listing shows the significance of the residual. This is the probability of the residual being as big or bigger than its value.

❹ Each line of the residual output contains the name of the source data file and line number from which the observation was read.

The updated station coordinate file

By default SNAP produces a new version of the coordinate file in which the station coordinates have been updated. This has the same name as the input coordinate file, but with extension ".NEW". That is, if the input coordinate file is "MYJOB.CRD" then the output file will be called "MYJOB.NEW". If the adjustment has completed correctly and there are no obvious errors in the data then the new file can be used to replace the original.

Usually the new file will include all the stations, including those which have not been adjusted. You can choose to exclude the rejected and ignored stations from the new file using the command "list no_rejected_station_coordinates" in the command or configuration file.

The binary data file

SNAP generally produces a binary data file which is used by SNAPPLOT and other post-processing programs (See the SNAP utilities manual). This contains information about the adjustment that has been done, the input data, and the resulting statistics. This file is given the same name as the command file, but with extension ".BIN".

The coordinate covariance file

If required SNAP can be made to produce a file listing the coordinates and covariances of the coordinates of all the stations in the network. This is a simply formatted ASCII file which may be used as input by other programs. The covariance matrix has the same name as the command file, but with extension ".CVR".

To obtain the covariance file the command file should include the line "output covariance_matrix".

Note that when SNAP is creating a covariance matrix it must invert the full normal equation matrix rather than the bandwidth limited version, so that it may be much less efficient for large adjustments.

Here is an example of the start of a covariance matrix.

```
! Lower triangle of coordinate covariance matrix
! Number of stations, number of coords per station
5
3
! List of stations
    1  41 19 06.240668 S 175 46 00.147510 E      734.0000
    2  41 17 22.857000 S 175 31 03.246300 E      581.3000
    3  41 11 38.626700 S 175 23 55.293100 E     1053.1100
    4  41 10 54.717996 S 175 39 07.082378 E      143.2900
    5  41 03 49.386211 S 175 35 03.760544 E      131.4960
! Lower triangle of coordinate covariance matrix
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
```

Appendix A:
Coordinate system definition

Coordinate systems in SNAP

The SNAP suite of programs use a single file which defines the coordinate systems that may be used. Usually this file is called COORDSYS.DEF and is located in the same directory as SNAP and its related programs. If you need to use coordinate systems other than those supplied by default then you will need to modify this file or create your own coordinate system file. This section describes the definitions of coordinate systems in COORDSYS.DEF.

To use your own coordinate system definition file you must specify the file with the DOS environment variable COORDSYSDEF. That is, if you have created a file called CSLIST.DAT in directory C:\MYSNAP then you should use the command:

SET COORDSYSDEF=C:\MYSNAP\CSLIST.DAT

What is a coordinate system

A coordinate system is a definition of how the coordinates of a point are determined from its physical position.

SNAP uses three types of coordinate systems. These are

- geocentric systems: the position is defined in a Cartesian system as X, Y, and Z coordinates. The origin is approximately the centre of the earth. The X axis extends from centre to the equator on the Greenwich meridian (0 degrees longitude). The Y axis extends from the centre to the equator at longitude 90 degrees East. The Z axis extends from the centre through the North Pole. Geocentric systems are not well supported by SNAP - in listing files they are always converted latitude and longitude.
- geodetic systems: the position is defined in terms of an ellipsoid by a latitude, longitude, and height above the ellipsoid. The ellipsoid is centred on the origin of the underlying geocentric coordinate system.
- projection systems: the position is defined by a projection northing and easting, and a height. The easting and northing are obtained by applying projection formulae to the latitude and longitude of the underlying geodetic system.

Each of these coordinate systems is based upon a reference system, that is a theoretically defined set of axes and (except for geocentric systems) a definition of an ellipsoid. The reference system is of little practical use for determining coordinates because it is expressed in terms of quantities we cannot directly observe (for example the centre of the earth).

To make the reference system useful we define a reference frame, which is a realization of a reference system. A reference frame adds the assigned coordinates of a set of measurable points to the reference system. We can make observations relative to these points to obtain the coordinates of other points in terms of the reference frame.

For example, the WGS84 (World Geodetic System 1984) reference frame is implemented in terms of the coordinates of a number of GPS tracking stations. These are used to calculate the orbits of the GPS satellites, which in turn are used to reduce GPS survey data of other points.

In New Zealand the NZGD49 (horizontal) reference frame is defined by the coordinates of the first order stations used in the 1949 adjustment. The vertical reference is defined by levelling from a number of tide gauges around the coast.

In both cases more stations are used to define the reference frame than are mathematically required. The coordinates are not perfectly consistent. That is, you could not construct a physical reference frame to exactly match the coordinates all the stations. Differences arise because of the errors in measuring the station coordinates and because the physical positions of the stations may have changed due to earth deformation since they were observed. This is particularly significant for the NZGD49 datum because: 1) the observations are relatively inaccurate (compared to GPS and modern EDM), 2) the analysis could not properly account for the gravity field, and 3) there has been significant deformation since the observations were made.

SNAP requires only the ellipsoid and projection information from the coordinate system. The location and orientation of the coordinate axes are irrelevant to its adjustments as all its calculations are done in a single system.

The location and orientation of the reference frame are used by SNAPCONV in order to convert coordinates between different systems and by SNGEOID to convert geoid undulations from the system they are defined in (WGS84) to the system of the coordinate file.

The coordinate system definition file

Structure of the file

The coordinate system definition file consists of three sections defining

- ellipsoids
- reference frames
- coordinate systems

Each section is starts with the name of the section enclosed in square brackets, e.g. [reference_frames]. Within each section are a number of definitions, one per line. For coordinate systems the definitions can be quite long. They may be extended over more than one line by ending each incomplete line with an ampersand (&).

Comments can be inserted anywhere in the file on lines starting with an exclamation mark (!). Blank lines and comments are ignored.

Ellipsoid definitions

Ellipsoid definitions have the following format

code “description” semi_major_axis reciprocal_flattening

where

code	is an identifier for the ellipsoid. This may contain letters, numbers, and the underscore character. It cannot contain blanks.
description	is a quoted text description of the ellipsoid

semi_major_axis	is the length of the semi-major axis in metres
reciprocal_flattening	is the reciprocal of the flattening

Here is an example of the ellipsoid definition section

```
[ellipsoids]
INTERNATIONAL "International ellipsoid" 6378388.0 297.0
WGS84 "WGS84 ellipsoid" 6378137 298.257223563
```

Reference frame definitions

Reference frames defines the ellipsoid for a reference frame, and the location, orientation, and scale of coordinates relative to a reference system. The reference system is arbitrary. Conversions can only be done between coordinates which have the same reference system.

Reference frame definitions have the following format:

code “description” ELLIPSOID ellipsoid_code refcode Tx Ty Tz Rx Ry Rz scale [transformation]

where

code	is an identifier for the reference frame. This may contain letters, numbers, and the underscore character. It cannot contain blanks.
description	is a quoted text description of the reference frame
ellipsoid_code	is the code for the ellipsoid associated with the reference frame. This code must have been defined in an earlier [ellipsoids] section of the file.
refcode	is a code identifying the reference system in terms of which translations, rotations, and scale are defined. This need not be the same a reference frame in the coordinate system file, but it must be the same for all reference frames between which coordinate conversions are required.
Tx Ty Tz	is XYZ position of the origin of the reference frame in the reference system (i.e. the translation that must be applied to coordinates to convert them back to the reference system). The coordinates are in metres.
Rx Ry Rz	are the rotations about the X, Y, and Z axes required to convert coordinates from the reference frame back to the reference system. The rotations are in arc seconds.
scale	is the scale difference between the reference frame and the reference system. It is applied to coordinates to convert them back to the reference system. The scale is defined in parts per million.
transformation	is an optional string definition of a transformation between the datum and the reference. The only supported option at present is “GRID SNAP2D *grid_file_name [description]*”. This uses a grid based transformation in which the 7 parameter transformation is modified by a latitude and longitude offset defined by bilinear interpolation on a grid.

Here is an example of the reference frames section..

```
[reference_frames]

WGS84  "World Geodetic System 1984" &
      ELLIPSOID WGS84 &
      WGS84 0.0 0.0 0.0 0.0 0.0 0.0 0.0

NZGD49 "New Zealand Geodetic Datum 1949 (Mackie 7 parameter)" &
      ELLIPSOID INTERNATIONAL &
      WGS84 59.47 -5.04 187.44 -0.47 0.10 -1.024 -4.5993 &
      “LINZ NZGD49-NZGD2000 conversion grid”
```

Coordinate system definitions

The coordinate system definition is formatted as

code “description” REF_FRAME ref_frame_code type [proj_definition] [RANGE extents]

In this definition the square brackets denote optional components. The components of the definition are:

code	is an identifier for the coordinate system. This may contain letters, numbers, and the underscore character. It cannot contain blanks. It is used in SNAP coordinate files to specify which coordinate system to use.
description	is a quoted text description of the reference frame
ref_frame_code	is the code for the reference associated with the reference frame. This code must have been defined in an earlier [reference frames] section of the file.
type	is the type of coordinate system. This can be one of “GEOCENTRIC”, “GEODETIC”, or “PROJECTION”
proj_definition	is the projection definition. It is only defined for projection coordinate systems. The contents of this definition depends upon the type of the definition. It is detailed for the supported projections in the following sections.
extents	optionally defines the range of coordinates over which the projection is valid. This is detailed below.

The coordinate system definition may optionally be followed by a range defining valid values for coordinates. This does not apply for geocentric systems. For geodetic systems the range defines the minimum and maximum latitudes and longitudes of the coordinates in decimal degrees. The format is

RANGE min_long min_lat max_long max_lat

For projection coordinate systems the range defines the minimum and maximum values of the easting and northing, formatted as

RANGE min_easting min_northing max_easting max_northing

The following example shows a geocentric and a geodetic coordinate system definition. Projection coordinate systems are illustrated in the following sections.

```
[coordinate_systems]
WGS84_XYZ  "World Geodetic System 1984 - XYZ" REF_FRAME WGS84
GEOCENTRIC
NZGD49 "New Zealand Geodetic Datum 1949" REF_FRAME NZGD49
GEODETIC
```

New Zealand Map Grid

For the New Zealand Map Grid projection the projection definition consists of just the text "NZMG". Here is an example of an NZMG coordinate system definition

```
NZMG "New Zealand Map Grid" REF_FRAME NZGD49 PROJECTION NZMG
```

Transverse Mercator Projections

A Transverse Mercator projection is defined the word "TM" and the following items

- the central meridian longitude in decimal degrees
- the origin of latitude in decimal degrees
- the central meridian scale factor
- the false origin easting in projection units
- the false origin northing in projection units
- the unit to metres conversion factor

Here is an example of a Transverse Mercator projection coordinate system. Note the use of "&" to continue the definition over two lines

```
AMUR  "Amuri Circuit"   REF_FRAME NZGD49  PROJECTION &
   TM 173.01013339 -42.68911658 1.000000 &
       300000.00 700000.00 0.999998261
```

Equatorial Mercator Projections

The Equatorial Mercator projection is defined by the word "EM" and the following items

- central meridian longitude in decimal degrees
- standard parallel in decimal degrees

Here is an example of an Equatorial Mercator projection coordinate system.

```
TEST_EM "Test equatorial mercator" REF_FRAME NZGD49 PROJECTION &
          EM  170 -40
```

Lambert Conformal Conic Projections

The Lambert Conformal Conic Projection is defined by the word "LCC" and the following items

- first standard parallel in decimal degrees
- second standard parallel in decimal degrees
- origin of latitude in decimal degrees
- origin of longitude in decimal degrees
- false easting in metres
- false northing in metres

Here is an example of a Lambert Conformal Conic coordinate system.

```
TEST_LCC "Test Lambert Conformal conic" REF_FRAME NZGD49 &
    PROJECTION LCC -40 -70 -45 170 300000 700000
```

Polar Stereographic Projection

The Polar Stereographic projection is defined by the word “PS” and the following items

- the word "North" or "South", defining the pole for which the projection applies
- the central meridian in decimal degrees
- the scale factor
- the false easting in metres
- the false northing in metres

Here is an example of a Polar Stereographic projection coordinate system.

```
TEST_PS  "Test Polar Stereographic" REF_FRAME NZGD49 PROJECTION &
         PS South 170 1.05 300000 700000
```

Gnomic Projection

The Gnomic projection is defined by the word “GN” and the following items

the origin of latitude in decimal degrees

the central meridian in decimal degrees

the false easting in metres

the false northing in metres

Here is an example of a Gnomic projection coordinate system.

```
TEST_GN  "Test gnomic" REF_FRAME NZGD49 PROJECTION &
         GN -45 170 300000 700000
```

Coordinate systems in the default COORDSYS.DEF file

The COORDSYS.DEF file supplied with SNAP contains definitions of the following coordinate systems.

Code	**Description**
NZGD49	New Zealand Geodetic Datum 1949
NZMG	New Zealand Map Grid
AMUR	Amuri Circuit
BLUF	Bluff Circuit
BULL	Buller Circuit
COLL	Collingwood Circuit
EDEN	Mt Eden Circuit
GAWL	Gawler Circuit
GREY	Grey Circuit
HAWK	Hawkes Bay Circuit
HOKI	Hokitika Circuit
JACK	Jacksons Bay Circuit
KARA	Karamea Circuit
LIND	Lindis Peak Circuit
MARL	Marlborough Circuit
NELS	Nelson Circuit
NICH	Mt Nicholas Circuit
OBSE	Observation Pt Circuit

Code	Description
OKAR	Okarito Circuit
PLEA	Mt Pleasant Circuit
PLEN	Bay of Plenty Circuit
POVE	Poverty Bay Circuit
TAIE	North Taieri Circuit
TARA	Taranaki Circuit
TIMA	Timaru Circuit
TUHI	Tuhirangi Circuit
WAIR	Wairarapa Circuit
WANG	Wanganui Circuit
WELL	Wellington Circuit
YORK	Mt York Circuit

Appendix B: File naming conventions used by SNAP

The following file names are used by SNAP and related programs.

File name	**Description**
COORDSYS.DEF	The coordinate system definition file, usually stored in the same directory as the program
GEOID.BIN	A binary file containing a gridded geoid model
*.CFG	A snap configuration file
*.SNP	A snap command file
*.CMD	Alternative name for snap command file
*.CRD	A station coordinate file
*.NEW	A station file after modification by SNAP or some other programs
*.LST	The listing file produced by SNAP
*.ERR	The error file produced by SNAP
*.BIN	The binary file produced by SNAP. This is used by several programs to analyse the results of the adjustment (eg SNAPPLOT)
*.CVR	A text format file listing the stations, their coordinates, and the covariances (optional)

Appendix C:
A description of least squares adjustment

This section provides a background to least squares estimation as used in SNAP and to some of the terminology used in this manual. The mathematical details of least squares adjustments are not presented here.

We use least squares and other fitting methods to resolve the problem of inconsistent data. That is we have made a number of **measurements** (or **observations**) from which we wish to derive some **parameters**. If we make more measurements than are necessary to define the parameters, then there are usually no values of the parameters which are consistent with all the measurements. In the surveying situation common observations would be angle or distance measurements. The parameters are usually coordinates of the survey stations.

A simple example is measuring the length of a line. The chances are that if we make more than one measurement, we will end up with different results. Generally we would take the mean value of our measurements as our best estimate of the true length of the line. This is in fact the least squares estimate of the length. The parameter in this case is the true length of the line.

If we measured the distance once using EDM, and once with a tape, we would expect the value from the EDM to be more accurate. In the least squares method we take this into account by giving more weight to the EDM measurement than to the taped value.

An important aspect of a least squares adjustment is that every observation has an associated expected **error**.

This estimate of the error will come from our experience and knowledge of the instrumentation used and the conditions in which the measurement was made.

The smaller the expected error assigned to an observation, the more influence that observation will have on the adjustment.

In this documentation I will use the word "error" rather loosely to mean the expected error associated with an observation. Saying that a distance measurement has an error of 10mm does not mean that it is 10mm from the true length of the line. It means that if we made a large number of measurements we would expect the standard deviation of the measurements to be 10mm.

Once we have made a set of measurements of the line we can estimate its length. Our best estimate of the length is the (weighted) mean value. This is not the true length of the line, of course. It is still an estimate, and so it has an expected error. The reason for using the mean of the measurements is that the expected error of the mean is less than that of any of the observations used to derive it.

Of course the least squares estimate of the length (the weighted mean) is not the only estimate we could make. Another option would be to take the median length. Various robust estimation techniques use different types of estimates. These are not used in SNAP.

We can use the estimates of the parameters to review the observations. Each observation can be compared with the corresponding value calculated from the parameters. The difference between the observed and calculated values is called the **residual error** (or just residual) for that observation.

The residual errors in the observations provide us with important information about the adjustment. The residuals should be consistent with the expected errors of the observations. If they tend to be larger than the expected error, then the expected errors may be under-estimated. Conversely, if they tend to be smaller, the expected errors may be over-estimated.

The information from the residuals is summarised in three important numbers, called the **sum of squared residuals**, the number of **degrees of freedom**, and the **standard error of unit weight.**

The sum of squared residuals is a weighted sum, taking into account the expected error of the observations. In fact one definition of the least squares estimates of the parameters is that they are the values of the parameters which result in the smallest value for the sum of squared residuals.

The degrees of freedom is simply the number of observations we have made minus the number of parameters we are trying to estimate. To put it another way, it is the number of spare observations we have got. It is these spare observations that provide a measure of the errors in the observations. In the simple example of measuring the length of the line, if we make three measurements then two are unnecessary, and there are two degrees of freedom.

The standard error of unit weight is an estimate of the error of our estimated errors of the observations. If it is close to one then it suggests that the expected errors of the observations are about right. If it is much less than one then the errors are probably over-estimated. If it is much over one they are probably under-estimated.

The standard error of unit weight is calculated by dividing the sum of squared residuals by the degrees of freedom and take the square root of the result.

Like all statistics, the more observations that go into calculating the standard error of unit weight, the more correct it is likely to be. When we are assessing the significance of the standard error of unit weight we should take into account the number of observations that have gone into it - the degrees of freedom.

In our example we might have assigned each observation an expected error of 1mm. Suppose we make 10 observations, and our sum of squared residuals is 900 (mm squared). We have one parameter, so that the degrees of freedom are 10 - 1 = 9. The standard error of unit weight is thus 10. We could infer from this that we had underestimated the errors of the observations by a factor of 10. Perhaps we should have assumed an expected error of 10mm for each observation?

Our belief about the errors may therefore change after the adjustment. Our initial estimates of the expected errors represent our state of belief before the adjustment, and are termed **apriori errors**. After the adjustment we can multiply the apriori errors by the standard error of unit weight. They will then represent our state of belief after the adjustment. Such errors are termed **aposteriori errors**.

Generally when we estimate parameters we also want some idea of how good those parameters are likely to be. For example when we have calculated stations coordinates we want to know the size of the error ellipse. The least squares methodology provides an algorithm for calculating the errors in the parameters from the expected errors of the observations. We can use either the apriori or a posteriori errors of the observations to derive the errors of the parameters.

There are several reasons why we choose to use a least squares estimate in preference to others. The two main reasons are:

- The expected error of the parameters is smaller if least squares estimation is used than if any other type of estimate is used. This is true only if the errors of the observations are normally distributed. Fortunately most types of errors affecting observations are approximately normally distributed.
- The least squares estimates are relatively straightforward to calculate and are well suited to computer programming.

There is also one significant problem with least squares estimation. The problem is that it cannot handle **gross errors** in the data well.

The least squares algorithm is permitted to change only the parameters, not the expected errors of the observations. If an observation contains a gross error then there will be a large residual on that observation. Such a residual is very unlikely on the basis of the expected error. The least squares adjustment is therefore obliged to distort the parameters to better fit the gross error. The gross error has an abnormally large influence on the parameters - precisely the opposite of what we want to happen.

After doing a least squares adjustment it is important to review the residuals of the observations to determine whether the data have been corrupted by gross errors. It is important to remember that even if only one observation is wrong there may be large residuals on a number of observations (due to the resulting distortion of the network).

A second problem with least squares adjustment is that it can only solve linear problems. A linear problem is one in which observations can be expressed as simple multiples of the parameters. Unfortunately this is not the case for survey networks. Calculating distances and azimuths from coordinates requires using trigonometric and transcendental functions.

It follows that we cannot use least squares to calculate network coordinates! However we can use least squares to refine coordinates that we have already approximated. We can do this because a small change in the coordinates causes a nearly proportional change in observations to the station (ie a small change in the coordinate is linearly related to the resultant small change in an observation).

To use the least squares method we have to assume that the coordinate changes are very small. However we may find that the least squares adjustment introduces large changes to the coordinates, invalidating our assumption.

To overcome this dilemma we use **iteration**. If an adjustment results in large changes then the adjustment is redone using the revised coordinates. This is repeated until the coordinates **converge** - that is until the calculated adjustments are small. This method is termed adjustment by **variation of coordinates**.

Before we do a least squares adjustment of survey data we need approximate coordinates for all the stations. These need not be very accurate, but they should be in the correct relationship to one another - if station 1 is north of station 2, then its approximate coordinates should not place it to the south. If stations are incorrectly located then the solution may fail to converge. The adjustment will become larger at each iteration rather than smaller.

One further problem can arise in least squares adjustment of survey data. That is that the observations do not provide enough information to determine station coordinates. For example, if you measure a network using only horizontal angle measurements you have no information about the scale, orientation, or location of the network (or about the elevations of stations). In this case there is no unique best fitting solution. A problem in which the observations are insufficient to determine all the parameters is called **undetermined**.

In least squares fitting a common solution to under-determined problems is to introduce some **constraints** on the solution. A constraint is a restriction on accepted solutions.

Constraints can arise quite naturally in survey adjustments, since often we are fitting data into an existing survey network. In this case the coordinates of some stations are held fixed. If no stations are fixed by definition then we have to arbitrarily choose some fixed stations to ensure that the adjustment has a unique solution.

Often when we are fitting data into an existing network the problem is over-constrained. That is, there are more constraints than are required to ensure a unique solution. In this case the constraints can be in conflict with the observations. For example if two stations are fixed in an adjustment then the distance between them is also fixed and will not be influenced by any measurements of that distance.

When you are holding stations fixed in an adjustment you need to be aware that apparent errors in the survey data could occur because the fixed stations are not correctly located.

That is, a large value for the standard error of unit weight may indicate that the observation errors are greater than we had expected, or it may indicate that the fixed station coordinates are not correct.

Appendix D: Installation

Installation

All the files distributed with SNAP must be placed into a single directory, for example C:\SNAP. The files that are required to run SNAP are:

- SNAP.EXE the SNAP program
- SNAPPLOT.EXE used for viewing the results of adjustments
- DOS4GW.EXE DOS extender used by SNAPPLOT
- COORDSYS.DEF coordinate system definition file

Any other utility programs should also be placed in this directory.

You should also put the SNAP directory into the DOS path. One way to do this would be to add a command to the end of your AUTOEXEC.BAT file containing something like

```
path %path%;c:\snap
```

(Assuming here the c:\snap is the location of the SNAP files).

System requirements

SNAP has no special system requirements. Ideally you should have a 386 or better computer with a numeric coprocessor, but these are not required (except by SNAP386). A mouse is useful, but not essential, with SNAPPLOT.

Release notes for this version

There are a few features in version 2.1 of SNAP that are incompatible with previous versions.

The format of the COORDSYS.DEF file (defining coordinate systems) has changed. It now defines the reference frame as well as the ellipsoid and projection parameters. This information is not used by SNAP, but may be used by other programs.

In the version 1 station coordinate file the coordinate system could be defined explicitly by specifying ellipsoid, and possibly projection parameters (for example “6378388 297 Ellipsoid”). In version 2 the coordinate system must be defined using a code (such as NZMG).

In version 1 data files the units of angle errors could be specified as “sec”, “secs”, “seconds”, or in fact just about anything starting with “sec”. In version 2 the units must be entered as “sec”.

In version 1, SNAPPLOT would identify station types (fixed, free, ...) from the configuration file. In version 2 it only shows the type if it is using a binary output file from SNAP.

In version 2.0D dated after 5 April the default reference frame for GPS data is “GPS” instead of “WGS84” as was previously the case.

Change log

3 September 1999: concord2.exe replaced with version 3.1. Changes default precision for heights when horizontal coordinates are in degrees, and fixes missing separator after last ordinate in the output file.

27 September 1999: Updated coordsys.def to fix incorrect false northing in North Island National Grid (yards) projection.

4 October 1999: Added gpstrans.bat to provide conversions of Trimble and Leica format GPS files to SNAP and LINZ observation contract format. Associated with this is the perllib directory tree, which is required for this to work.

19 October 1999: Minor update to snapplt3.exe to correctly display standardised residuals of selected lines.

2 November 1999: Modified snap2stn.bat to handle negative heights.

4 November 1999: Modified directory structure to create SNAP directory with SNAP programs and subdirectories, separate from other installation directories.

7 November 1999: Added snapconv32 which should be able to handle much larger station files than snapconv.

30 November 1999: Updated trv2snap to allow it to read Round 4 station and traverse data files. Updated snap2stn to create Round 4 coordinate files.

10 December 1999: Updated gpstrans.bat and SkiFile.pm. Dates in SKI files are now assumed to be in US format (MDY). Also @1 or @4 records can now be used to hold the station name, if present. Otherwise the code is used.

15 December 1999: Updated gpstrans.bat to handle times which do not include decimal parts of a second.

11 February 2000: Minor fix to trv2snap to allow it to correctly handle Round 4 station files.

17 February 2000: Modifications to trv2snap to handle blanks lines in obs and station files.

8 March 2000: Modification of gpstrans.bat and perllib/GPS.pm to rectify errors in generating contract data file .. date format needed to by yyyy.ddd instead of yyyy.mm.dd, header was wrong, and class was not being output.

23 March 2000: Updated coordsys.def to use the correct spheroid for the Chatham Island datum.

24 March 2000: Added rej2dat.bat to generate a dummy data file identifying the vectors which failed the accuracy specifications.

7 April 2000: Put the SNAP files under CVS revision control. Changed contractors distribution to use Windows 32 console versions of all programs except SNAPPLOT. snap32 replaces snap and snap386. Only purely DOS based application is now SNAPPLOT and SNAPPLT3.

30 April 2000: Removed ITRF92 from coordinate systems as no longer used by LINZ

24 May 2000: Updated definition of CHAT1979 reference frame

29 May 2000: Changed default geoid model from OSU91 to EGM96

7 June 2000: Minor update to trv2snap to improve finding snapconv program

13 June 2000: Update to gpstrans.bat to use backslashes in file names

20 June 2000: Removed AGD66 coordinate system and unsourced Antarctic system

17 October 2000: Renamed NZGD49 coord sys to NZGD1949 for consistency with Landonline

24 October 2000: Renamed and recoded 1949 meridional circuit and national grid coordinate systems for consistency with Landonline.

1 November 2000: Fixed error in gpstrans.bat relating to finding perl library directory.

8 November 2000: Updated gpstrans.bat to calculate missing distances when these are needed to derive expected errors of bearings.

9 November 2000: Modified definition of NZMG coordinate system to include the valid range of the coordinate system

18 January 2001: Fixed error in SNAP exceeding a character buffer for coefficient names.

17 April 2001: Updated Chatham Island coordinate systems including CHATTM2000

29 April 2001: Replaced geoid.bin file calculating EGM96 geoid heights – version installed on 29 May 2000 was not correct.

6 May 2001: Minor fix to trv2snap

14 May 2001: listgps program added to SNAP distribution

27 June 2001: Updated listgps program to allow tabulation of data for stations in the adjustment.

4 July 2001: Updated snap to fix bug whereby most significant residuals were no listed for V large adjustments.

26 July 2001: Fixed but in handling of errors (apparently existing since 7/11/2001)

26 July 2001: Modified snapplot to show classifications in alphabetical order.

10 August 2001: Changed snap compiler options to handle changes to default data alignment with the new version of the bcc32 compiler

7 October 2001: Updated IGNS98 grid model with more detailed model that covers entire landmas of NZ (previous version was coarser and had some holes near the coast).

16 October 2001: Added definition of NZTM projection to coordsys.def

17 October 2001: Changed algorithm used for Transverse Mercator projection to be consistent with NZTM documentation and GDA technical manual

9 October 2002: Fixed errors in listgps. Removed 16 bit executables (snapplot, listgps) from distribution. Modified makefile for current Borland C++ software (use ilink32 instead of tlink32, OS is a special variable in makefile so cannot be used as a macro (?)

14 May 2003: Added facility to output coordinate changes with listgps

16 May 2003: Fixed bug in testing of specifications (rounding error leading to unchecked sqrt of negative number).

23 October 2003: Added absolute accuracy tests to specification testing command. Fixed ellipsoidal distance calculation error in listgps.

24 November 2003: Updated specification tests to not include rejected stations. Updated iteration listing to show number of stations exceeding tolerance. Updated SNAP to accept .snp as default command file name to avoid issues with .cmd file being treated as a list of commands by MS Windows. Updated SNAP to handle bearing projections in coordinates systems other than that of the

coordinate file. Removed redundant SNAPPLT3 from distribution, as it is the same as SNAPPLT. Updated SNAP to ensure that when it requires a full inverse matrix it still uses minimum matrix size (bandwidth optimised) until it actually calculates the inverse. Updated concord2 to be able to use a grid based transformation for NZGD49-NZGD2000 conversion. Changed SNAP version number to 2.15, and concord2 version number to 3.2.