GPS - System 300

SKI Documentation

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In order to use the software correctly and reliably, you must follow the instructions given in the user manual or in the on-line help system. You must also adhere to the directions given in the user manual for the product with which you are using the software.

The rights and responsibilities accruing in respect to Leica as a result of acquisition of the software are set out in the Leica Software License Agreement. To secure your rights with regard to the software acquired, it is essential that you follow the directions given on the Leica Software - Support Registration Card.

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CONTENTS

SECTION 1 - SKI - GETTING STARTED

1 Introduction

Welcome to SKI, the Static KInematic post processing software for Leica GPS Survey Systems.

SKI is the software package that accompanies Leica System 200 and System 300 GPS Hardware. It can be used for mission planning, data processing, network adjustment and datum transformation. In addition to this, data from third party receivers can be imported using the RINEX format and processed.

1.1 License Agreement and Software Support

Read the Software License agreement carefully before opening the package containing the installation diskettes.

Fill out and return the Software Support Registration Card during installation of the software or immediately afterwards. When this card is received by us you will become a registered user and be able to receive software support without any problems.

2 Manual Concept

This printed manual contains the information necessary to get you started and guidelines to the more complex operations in SKI. A very comprehensive help system is included in SKI itself and this should be used as a first point of reference should you experience difficulties operating SKI.

As referred to above, the final three chapters of this manual are guidelines to the more complex operations within SKI. These give advice and detailed descriptions of how to operate the software successfully. The SKI components that are covered in the guidelines are:

- Data Processing
- Adjustment
- Datum/Map

3 Installation

3.1 System requirements

The computer and system software you intend to use with SKI must meet the following requirements. Note that SKI works best with the recommended requirements.

Component	Recommended	Minimum
Computer	IBM PC or Compatible Pentium or 80486DX processor (or 80486 with math co-processor) 8MB RAM or more 250MB Hard disk or more 3.5" Diskette drive 9 pin RS232 COM port Parallel Port (for software protection key)	IBM PC or Compatible 80386 with math co-processor 4MB RAM 60MB Hard disk 3.5" Diskette drive 9 pin RS232 COM port Parallel Port (for software protection key)
Monitor	VGA or higher resolution	VGA
Mouse	Installed & functioning on PC	Installed & functioning on PC
DOS version	5.0 or later	3.1
Windows version	3.1 or later	3.1

3.2 Before you install

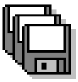
Ensure that your computer and software conform to at least the minimum requirements as outlined above.

SKI requires at least 16MB of free disk space. The programs on the installation diskettes are compressed and will be expanded during installation.

The first installation diskette will usually contain a file called "*README.SKI*". This file is in ASCII format and it is advisable to read it prior to installation. It may contain information not yet included in the manual.

Make a backup copy of the installation diskettes. It is recommended that these backup diskettes are write-protected to prevent accidental overwriting or deletion of files. Use the "Copy Disk..." command in File Manager to create the backups. This will give the backup diskettes the same volume labels and diskette contents as the originals.

3.3 Installing for the first time



To install SKI:

1. Start Windows and insert Diskette 1 into drive A: or drive B:

2. Ensure no other applications are running. From the Program Manager choose "Run..." from the File menu. In the Command Line box type *A:\SETUP* or *B:\SETUP* and click on [OK]

3. When the setup screen disappears, the SKI Installation screen is displayed. You are asked which files you wish to install. The Program Files, Database Files and Geoidal Model are selected by default. Note that the card reader box is for the MEL-PC card reader, not the OMNIDrive PCMCIA card reader. The OMNIDrive card reader must be installed separately after the installation of SKI (See next section). If you wish to install the MEL-PC card reader, click on the check box. Click on [OK].

4. Specify the drive and path for the SKI Program Directory. By default the path C:\SKI\PROG is suggested. Type in a different path if required. Click on [OK]

5. The same is prompted for the SKI Database Directory and the SKI Working Directory. Follow the same procedure as in step 4 above.

6. The specified directories are created and checked and SKI installed. Insert the remaining disks in turn when the prompt appears.

7. SKI is installed in a new program group called SKI. You will be prompted to restart windows to complete the installation.

Installing the OMNIDrive card reader.

The OMNIDrive is supplied with an installation diskette.

With the SKI software protection key in place, connect the OMNIDrive card reader to the back. Any printer that was connected may now be connected to the rear of the OMNIDrive.

1. Insert the installation diskette into Drive A: or Drive B:

2. From DOS type *A:\INSTALL E* or *B:\INSTALL E* to install in English. A German installation program is available by typing *A:\INSTALL* or *B:\INSTALL*.

3. The installation will begin by asking you where to install the OMNIDrive. Accept the default path of C:\OMNI\.

4. Accept the further default values that appear during the installation.

5. Lines are added to the CONFIG.SYS and AUTOEXEC.BAT files in order that the OMNIDrive is configured when the computer is started.

Note: When installing the OMNIDrive over an old version of SKI that had the MEL-PC card reader installed, it is important that the MEL-PC is not called upon boot up of the computer. In the CONFIG.SYS either remove the line that calls the MEL-PC card reader or insert a REM statement.

3.4 Installing over an older version

If you are installing SKI v.2.0 or later over a previous installation of SKI v2.0 or later, you will be informed that an old database has been detected and asked whether you wish to take it over into the new installation between steps 3 and 4 above.

If you are installing SKI v.2.0 or later over SKI v.1.09 or earlier and wish to take database information over into the new installation, several steps are required due to the large differences in the two database structures.

Use the following procedure:

1. Backup the existing Projects you wish to take over. (It is important to do this in case you wish to use the Projects again with SKI 1.09 or earlier versions.

2. Follow steps 1 to 3 from the previous section. You will then be prompted that an old database has been found. To take over the Transformation Database (data stored in Datum/Map) and the Global Database (Header text, almanac information, paths to projects but not the projects themselves etc.), click on the appropriate check boxes and click on [OK]. This takes over the Transformation database and the Global Database but not the Project database.

3. Complete the installation steps 4 to 7 from the previous section

4. When Windows has restarted, activate SKI and select Project and then Update.

5. Type in the path where the old Project is stored and a name for this Project. Click on [OK]. You will be notified that this is an old project. To proceed click on [OK]. The project will be updated and added to the current Project list.

3.5 SKI and the Config.sys file

In some cases it may be that you get the error message "Out of Environment" when trying to run SKI. In this case add the following line to the Config.sys file:

SHELL=C:\COMMAND.COM /P /E:1024

This assumes the Command.com file is directly under the root. If this is not the case, specify the path.

Ensure that there is a line in the Config.sys file that reads:

FILES=30

The number of files must be set to at least 30. Values greater than this may also be used.

Failure to ensure this may result in database errors.

3.6 SKI and the Autoexec.bat file

During SKI installation, the following lines are added to the Autoexec.bat file:

SET DBGLOBAL=C:\SKI\DB\DBGLOBAL
SET DBPROJ=C:\SKI\DB\DBPROJ
SET DBTRANS=C:\SKI\DB\DBTRANS

These set the SKI databases. They should always be set before Windows is started. On some computers that have a line in the Autoexec.bat that starts windows, the SET commands may appear in the wrong place. If this is so, you will receive a message when you try to start SKI. Simply move the line starting Windows so that it is after the SET commands.

4. A brief overview of SKI and it's options.

SKI runs within Microsoft® Windows™ v.3.1, 3.11, 95 or NT. This is a graphical operating environment which greatly simplifies and speeds up work with the computer. Those who are already familiar with Windows will find SKI very easy to handle. Those with no prior knowledge of Windows will find it quick and easy to learn.

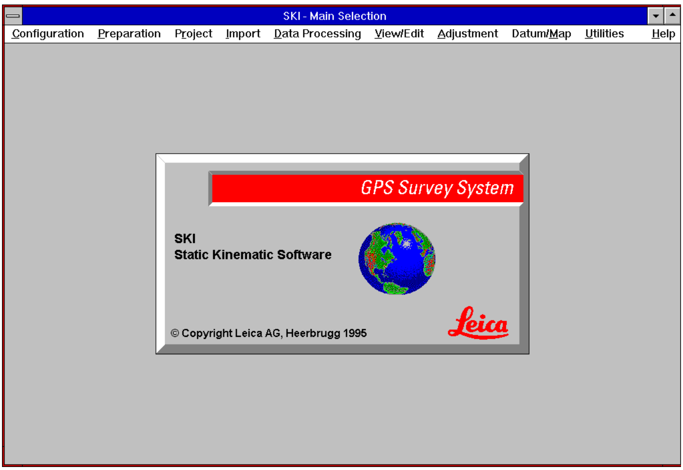
Note that when running SKI under Windows NT, special drivers are required. These are available from your local Leica representative.

4.1 Starting SKI

Ensure that the green software protection key is inserted into the parallel port of your computer.

To start SKI simply double click on the SKI icon within the SKI Program Group within Windows.

The SKI Main Menu screen will appear as below:



The various components of SKI can be accessed from this menu by double clicking on the component or by using the key combinations. To use a key combination to activate a menu, hold down the ALT key and press the letter that is underlined. (E.g. to select Configuration, press ALT C).

4.2 SKI components

As mentioned previously, SKI consists of several components. Some of these components are delivered as options which gives the user the opportunity to select the combination which best suits their needs and budget.

The standard components delivered with every copy of SKI are:

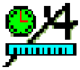
Configuration
Preparation
Project
Import
Data Processing
View/Edit
Utilities

The options available for SKI are:

Network Adjustment component
Design and Adjustment (allows input of terrestrial measurements and design of networks also)
Datum/Map component
RINEX data format import
Auto Program option
AROF - Ambiguity resolution on the Fly option

In addition, SKI contains a very comprehensive help system which should always be used as the first point of reference should operation difficulties arise. More details about the help system are contained in section 5.

4.2.1 The Configuration component



The Configuration component enables you to configure the type of units you wish to use and define a header that will appear on all print outs that you make from SKI.

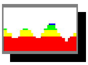
Additionally, you may configure the Program type to use (if the Auto Program option has been purchased) and to configure parameters for the local coordinate system (if the Auto Program option has been purchased).

Further details are contained in the relevant SKI help file.

4.2.2 The Preparation component

The Preparation component contains three sub-menus. These are:

Survey Design
Attributes
Waypoints



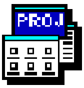
Survey Design allows you to display and print predicted satellite information in various forms and to input obstructions (buildings, trees etc.) for a given site in order to find the most suitable time for satellite observations.

An attribute list may be defined and uploaded to the Controller. These attributes will only be used by users running Controllers with firmware version 2.33 or lower. These earlier firmware versions do not support the Open Survey World file formats.
Users with Controllers running firmware version 3.20 or higher will find the improved equivalent of Attributes in the Leica Workbench program Codelist Manager.

A waypoint list may be defined and uploaded to the Controller. Similarly, Waypoints will only be used by users running Controllers with firmware version 2.33 or lower. These earlier firmware versions do not support the Open Survey World file formats.
Users with Controllers running firmware version 3.20 or higher will use 'Targets" selected from the point list contained on the Controller. To use this system, points may be either input manually into the Controller or defined in an ASCII file and converted to GEODB format using the Workbench Data Manager prior to uploading to the Controller.

Further details are contained in the relevant SKI help file.

4.2.3 The Project component



All GPS data that is collected and that belongs together can be organised in SKI within a single Project. This Project could contain for example all data relating to a particular contract you are carrying out for a client.

In the Project manager you can create, open, and edit projects as well as update projects not contained in the project list.

Further details are contained in the relevant SKI help file.

Important: Note that you should <u>never</u> delete a project or any of the files contained within a project from outside SKI. <u>Always</u> use the Project Manager to delete unwanted Projects. Deletion of Projects or Project files from outside of SKI can result in the destruction of the consistency of the database, which will lead to unrecoverable database errors.

4.2.4 The Import component

The Import component is used to transfer data into SKI. It is possible to transfer GPS raw observations for post-processing along with related point information as well as coordinates recorded using the real time RT-SKI option.

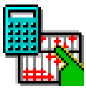
You may import from:

The GPS Controller itself
A memory card using the card reader
A backup diskette or PCMCIA card in the computer's PCMCIA slot.
A RINEX file. (See section 4.2.10)

Additionally, there is the facility under Satellite data to import a precise ephemeris.

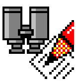
Further details are contained in the relevant SKI help file.

4.2.5 The Data Processing component



The Data Processing component allows you to process GPS observations that have been recorded in the field to achieve WGS84 coordinates and their relative accuracy. Static, rapid static, stop and go, kinematic, kinematic on the fly, reoccupation and single point data can be processed. For more information on Data Processing, refer the relevant help file within SKI and also to the chapter Guidelines to Data Processing within this manual.

4.2.6 The View/Edit component

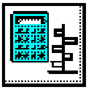


The data contained within the Project may be viewed and edited graphically using this component. In addition to the display and editing of data and information you may:

Display related data such as azimuth and distance between points.
Filter out points that you do not wish to display.
Export the information in a variety of formats.

Further details are contained in the relevant SKI help file.

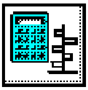
4.2.7 The Adjustment component (optional)



The Adjustment component provides the user with a powerful tool for performing a least squares adjustment on a network of baseline vectors in the WGS 84 coordinate system. Data can be imported directly from any SKI project or from a suitably formatted ASCII file. Free or constrained adjustments can be performed. A graphical user interface similar to that of View/Edit is used.

Further details are contained in the relevant SKI help file and in the chapter Guidelines to Adjustment.

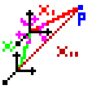
4.2.8 The Design and Adjustment component (optional)



The General Adjustment component allows you to carry out similar operations to the adjustment component and also offers a more comfortable user interface, the possibility to introduce terrestrial measurements and the possibility to design networks.

Further details are contained in the relevant SKI help file.

4.2.9 The Datum/Map component (optional)



As coordinates derived using GPS are in the WGS 84 coordinate system most users will need to transform them onto the local grid system for the area in which they are working. Datum and Map is a powerful tool for determining and applying transformation parameters to achieve coordinates in a chosen system.

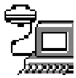
The major functions of this component are:

- Creation of coordinate sets, ellipsoids, transformation parameter sets and projection sets. (Most of the commonly used ellipsoids are already defined).
- Determination of transformation parameters. There are four methods available for determining transformation parameters.
- Map projections may be defined and applied. User defined map projection programs may also be integrated.

• User defined Geoidal model programs may be integrated. (A global model based on the WGS84 ellipsoid is supplied and is accurate to a couple of metres or so).
• Transformation of coordinates from one system to another.

Further details are contained in the relevant SKI help file and in the chapter Guidelines to Datum/Map.

4.2.10 The Utilities component



The Utilities component contains programs for uploading system (firmware) upgrades to the Controller and Sensor.

In addition to this, there is a program that allows you to merge time tagged data recorded on a Leica Time Digitising Unit (TDU) with a simultaneously recorded, post processed kinematic chain.

Further details are contained in the relevant SKI help file.

4.2.11 The RINEX option

RINEX stands for Receiver Independent EXchange format and is a standard format for GPS data. Many manufacturers of other GPS equipment and software provide a RINEX output in their software. This is so in SKI, the RINEX output is a standard feature.

RINEX input however is an option for SKI and allows you to input RINEX data collected by third party receivers via the Import component.

Further details are contained in the relevant SKI help file and in the booklet "Guidelines on Processing RINEX Data with SKI".

4.2.12 The Auto Program option

The Auto Program is designed so that SKI may be run in a highly automated mode. It is envisaged that it will be used in situations where the same reference points are almost always used.

You may automate all or a combination of the following procedures:

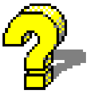
- Backup of imported data.
- Immediately compute baselines after Import. Baseline selection is automatic.
- Storage of computation results
- Export of results to a standard SKI format or to one of a range of formats from other software manufacturers. A transformation may also be automatically applied.

Further details are contained in the relevant SKI help file.

4.2.13 The AROF option

AROF stands for Ambiguity Resolution On the Fly and is an option for the data processing component. It will enable you to process data collected by the Controller running a Kinematic On the Fly (KOF) mission. A Kinematic On the Fly mission does not require a static initialisation. If you do not have the AROF option you will not be able to process data collected using a KOF mission.

5 The SKI Help System



The SKI Help System is very comprehensive and goes a long way toward replacing the role of a traditional printed manual. Information is available on-line and is based on the Windows help system although there are also a few additional features.

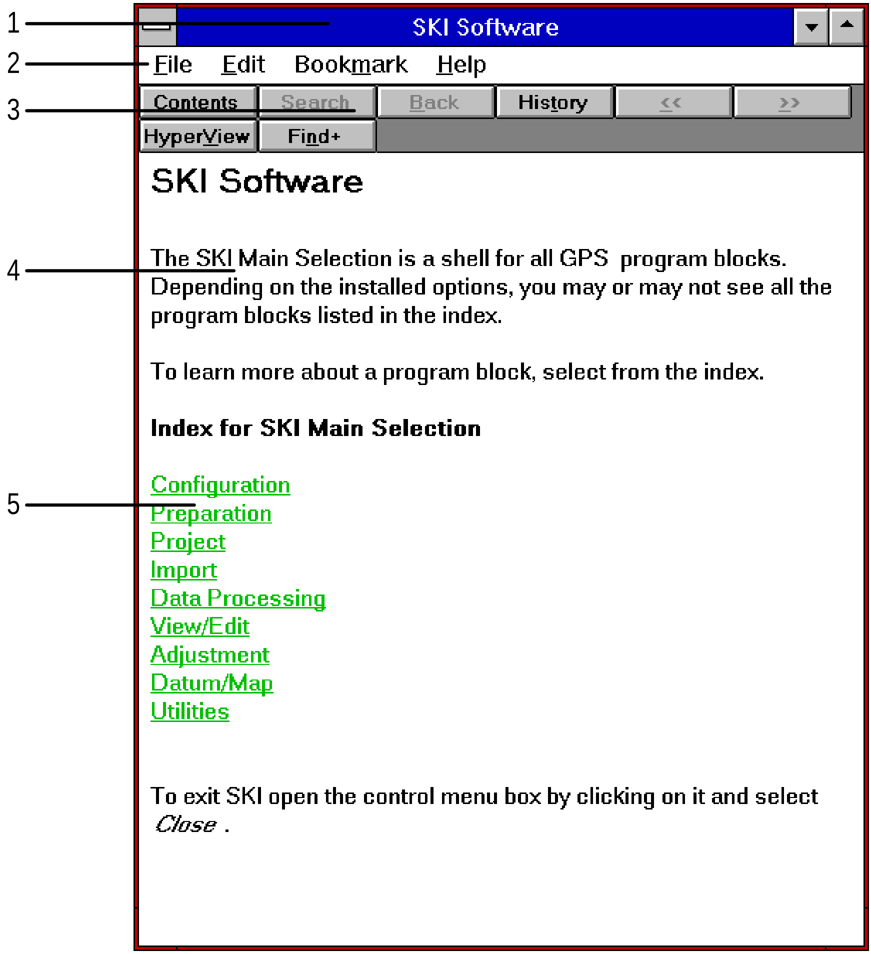
5.1 Accessing the Help System

The Help System can be accessed from any screen within SKI by clicking on Help in the top right hand corner and selecting Index from the menu or by typing ALT H followed by ALT I. Alternatively, pressing F1 will also call the Help System.

Selecting Help from the SKI Main Menu will give you the full list of all the components from which to choose. Selecting Help whilst in a component of SKI will only give you Help relevant to that component.

5.2 The Help Screen

When the Help System is activated and during it's use, a new window will appear across the right hand side of the screen. This is the help window, a typical example of which is shown over.



1 - Title Bar
The title of the Help file chosen is displayed in this bar.

2 - Menu Bar
The Menu Bar contains various menus from which you may choose commands.

3 - Button Bar
The Button Bar contains buttons that perform many of the commands contained in the menus on the Menu Bar.

4 - Help topic text
The Help text is shown in the main part of the window. The title of the chosen topic is displayed in large bold text at the top of the window. The main body of the help text appears below. In some cases you may need to use the scroll bar on the right hand side of the window (not shown in this example) to access all of the Help text.

5 - Jumps
Any text in the Help text that is coloured green and underlined is known as a jump. This is a link to an associated Help topic. To use the jump and access the associated topic, move the mouse cursor over the green text so that it is displayed as a hand and click once with the left button.

5.2.1 The File Menu

The File Menu contains the following commands:

Open - Allows you to open another help file. After selecting Open, input the path and select the help file (with the file extension .hlp) and click on OK.

Print Topic - Will print the currently displayed help topic to whichever printer is currently configured.

Print Setup... - Will allow you to setup the current printer or select a different installed printer.

Hyperview - Calls the WinHelp Hyperviewer which will produce a graphical overview of the help file. The Hyperviewer is discussed in greater detail in section 5.4.

Find + - Calls a comprehensive search program from which you can search for specific text within the help file. The Find+ program is discussed in greater detail in section 5.5.

Exit - Quits the Help system.

5.2.2 The Edit Menu

The Edit menu contains the following commands:

Copy - Allows you to copy the current Help topic to the clipboard for pasting into other Windows applications.

Annotate - Enables you to make your own notes about the current Help topic and attach them to that Help topic. When a note has been made about a Help topic and saved, a green paper clip appears next to the Help topic title. Click on the green paper clip to view the notes.

5.2.3 The Bookmark Menu

The Bookmark menu contains only one command but if bookmarks have already been added, a list of these will also appear. Clicking on a specific bookmark will immediately activate that help topic.

Define - This command allows you to define where a bookmark is to be placed. Once you have entered a name for the bookmark (the help topic title is suggested as default), it will appear in the bookmark list for the current help file. Click on the required bookmark from the list to jump directly to that help topic.

5.2.4 The Help menu

The Help menu contains the following commands:
How to use Help - Is a help file for the help system. It tells you how to use Help.
Always on Top - Is a command that will always keep the Help window uppermost. i.e. It will always be displayed.
About Help - Gives product information about the Help system.

5.3 The Button Bar

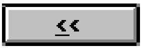
The Button Bar contains several buttons, the function of which is explained below.

The Contents button jumps to the first page of the Help file.

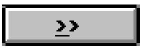
The Search button (if active) will allow you to search for terms contained in the Help File. Users may find it easier and more useful to use the Find+ button.

The Back button steps back to the last help topic that was displayed.

The History button will bring up a dialogue box showing you which help topics you have activated during any one session in Help.



The Browse Backward (<<) button will allow you to move backward to the previous help topic in the sequence.

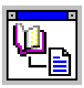


The Browse Forward (>>) button will allow you to move forward to the next help topic in the sequence.

The Hyperview button activates the Winhelp Hyperviewer. Refer to the next section for a full explanation.

The Find+ button activates a full text search function. Refer to section 5.5 for a full explanation.

5.4 The WinHelp Hyperviewer



The WinHelp Hyperviewer is an expandable/collapsible view of the Help system. It works in a similar fashion to the Windows File Manager and appears as a window containing books and pages which graphically illustrate links and jumps within the Help system.

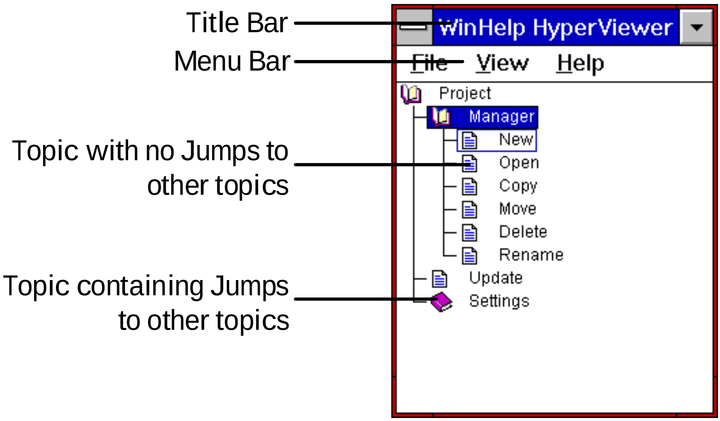
The Hyperviewer can be activated either from the File menu or from the Hyperview button.

The Hyperviewer can perform the following operations:

- Graphical overview of the Help System structure
- Navigate through the Help System
- Print selected topics from the Help System
- Print the whole Help System

5.4.1 Navigating through Help using the Hyperviewer

When the Hyperviewer has been created, a new window appears, a typical example of which is shown.



The window displays an overview of the help system with each topic being allocated one of three symbols.

A closed book signifies a closed topic containing jumps or links to other topics.

An open book signifies that this topic has been expanded. The topics to which it is linked are displayed in the tree below.

A page signifies a topic which has no links to further topics.

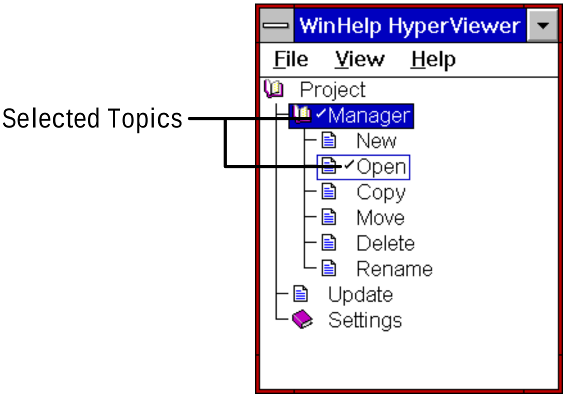
To open a Help topic using the Hyperviewer double click on the topic from the graphic display.

To expand a closed book to view the topics that are linked to it, double click on the closed book in the graphic display.

5.4.2 Printing from the Hyperviewer

The Hyperviewer can be used to print out a selection or all of the Help topics. This may be useful if you wish to keep a hard copy of the Help to use as a printed manual.
The print commands are located in the File menu.

To print a selection of topics, first select the topics you wish to print from the graphical display by pressing and holding down the CTRL key whilst clicking on the topic, or by pressing and holding down the SHIFT key whilst pressing the left mouse button and dragging the cursor over a number of topics. Selected topics will be marked with a black tick.



After selecting the topics, choose **Print Selected Topic(s)** from the File menu.

To print all topics, select **Print All Topics** from the File menu.

5.4.3 Customising the Hyperviewer display

The Hyperviewer display can be customised using the commands contained in the View menu.

Displaying unlinked topics. Occasionally, a topic exists within a help system that is not referenced or linked to any other topic. To display these unlinked topics select **Unlinked Topics**.

Displaying the current branch. Sometimes when using the Hyperviewer the tree can be expanded to 4 levels or more and can get rather cluttered. To display the branch that is currently active only, select **Current Branch Only**.

To keep the Hyperviewer as the uppermost window at all times, select **Always on Top**.

The display font, font size and style can be selected from the **Font** command.

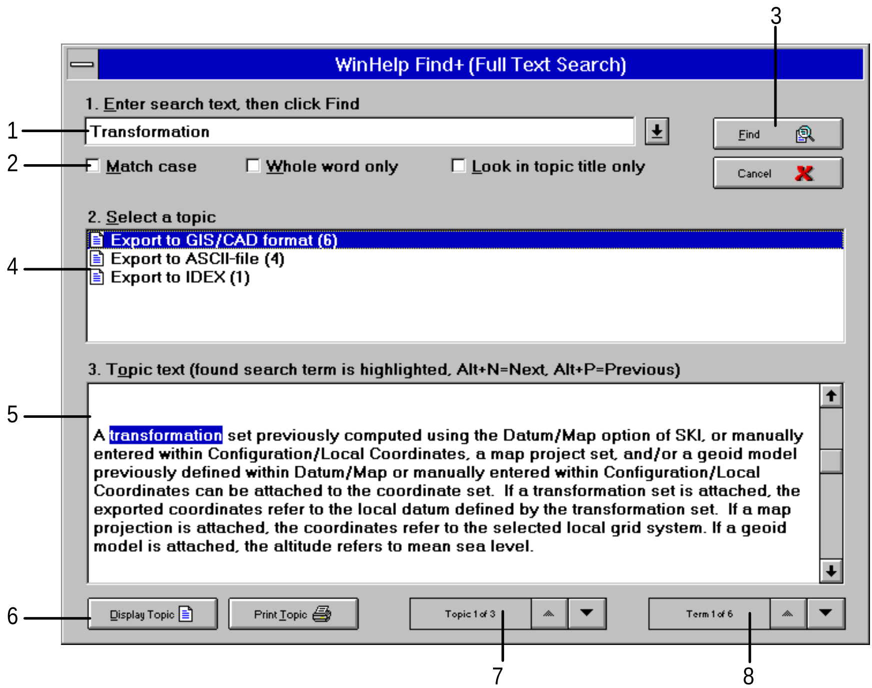
5.4.4 Hyperviewer Help

Help on the Hyperviewer is available via the Help menu. Information about the Hyperviewer is also available from this menu.

5.5 The Find+ function

The Find+ function allows you to perform a full text search throughout the entire Help system.

The Find+ function is activated either by clicking on the Find+ button or by selecting **Find+** from the File menu.



1. - The text for which you wish to search is input here.

2. - If required, select search options for the text from these check boxes.

Match case will make the search case- dependent, matching the uppercase and lowercase letters exactly as you entered them.

Whole word only finds only entire words or phrases that match what you entered. E.g. searching on "Trans" would find the word "Trans" but not "Transformation".

Look in topic title only searches just the topic titles for the word or phrase.

3. - Click on the Find button to commence the search.

4. - When the search is complete, the topics containing the search text are listed in this box. The number of times which the search text occurs in each topic is shown in brackets.

5. - The topic text is displayed in this box according to which topic has been selected from the previous box. Each found search term is highlighted.

6. - Click on the Display Topic button to display the selected topic in the Help System. Click on Print Topic to print this topic out.

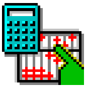
7. - The topic currently selected is displayed out of the total number of topics containing the search text. Click on the up or down buttons to move to the previous or next topic.

8. - The currently highlighted term is displayed out of the total number of terms contained in the currently selected topic.

When you have finished using the Find+ function, click on Cancel to close the dialogue box.

SECTION 2 - Guidelines to Data Processing

7 Guidelines to Data Processing - Introduction



This section of the manual deals with how to go about using the Data Processing component of SKI and how to analyse results produced by the Data Processing component. It also includes suggestions on how to proceed in case of difficulties with data processing.

7.1 Suggested method of working

It is always best to select one reference point as the starting point and then compute the network out from this point in a logical manner. The basic procedure is:-

1. Derive coordinates of the "first" Reference Station in WGS84 to an accuracy of 10m or so.
2. Process the baselines to any other stations you intend to use as reference stations in future processing runs.
3. Process the baselines between reference and rover stations.

7.1.1 Derivation of Coordinates for the Reference Station

For the computation of <u>every</u> baseline the following rule applies:
The coordinates of one point (reference) are held fixed, the coordinates of the other points (rover) are computed relative to it.

In order to avoid that the results are influenced by systematic errors, the coordinates for the "fixed" point of the baseline have to be known to within about 20 meters in the WGS 84 coordinate system. Whenever possible, the WGS 84 coordinates for the "fixed" point should be known to within about 10 meters otherwise scale errors of about 1 to 2 ppm will be introduced.

This means that for any precise GPS survey the absolute coordinates of one site in the network have to be known in WGS 84 to about 10 meters. WGS 84 coordinates for one site will often be available or can be easily derived by setting the reference station at a point known in the local coordinate system. Then, using approximate transformation parameters (usually obtainable from the local Survey Department or University), you can transform the grid coordinates back into WGS 84 coordinates.

If WGS 84 coordinates for one site are not known or cannot be derived, the Single Point Position computation in SKI can be used. Remember, however, that Selective Availability (SA) is usually switched on. The only way to overcome SA is to observe for sufficient time for the effects of SA to be averaged out in the Single Point Position computation. More details are given in section 7.2.1 Single Point Processing.

The reference receiver will usually observe for several hours as the rover moves from point to point. In such a case, the Single Point Position for the reference receiver computed in SKI should be relatively free from the effects of SA.

If a Single Point Position is computed from only a few minutes of observations, the effects of Selective Availability will not be averaged out. The result could be wrong by 100m or more due to SA.

When computing the Single Point Position for the starting point of a network, always compute for a site for which you have several hours of observations. The resulting WGS 84 coordinates should then be correct to within about 10 metres.

The minimum observation for the computation of a reliable Single Point Position is probably about 1 hour with four or more satellites and good GDOP. The longer the observation time, the better the Single Point Position will be.

7.1.2 Processing the Baselines

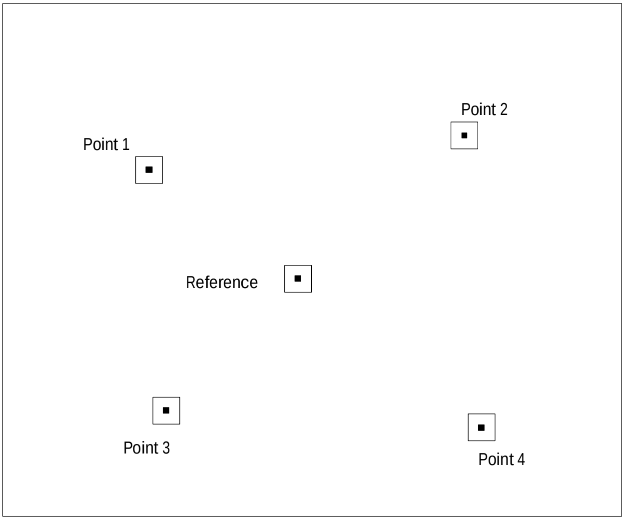
Compute and build up the network in a logical manner in order to ensure that you always have good WGS84 coordinates for the starting point (reference) of every baseline.

If you have the possibility to process using two reference stations, you should first process the line from the initial reference station (the one with good WGS 84 coordinates) to the secondary reference station. Store the results to fix the secondary reference station. Then select the rover stations and compute the baselines using both the initial reference station and the secondary reference station. Build up the network in this way

7.1.3 Practical Example 1 - Single reference station

Day 1

The points below were measured using Rapid Static.

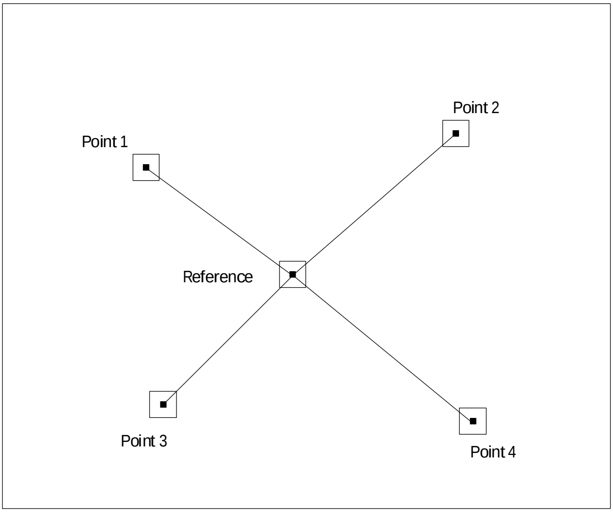


The processing is carried out as follows:

1. Select Single Point Processing mode and process the reference point "Reference" as a single point. Store the result.

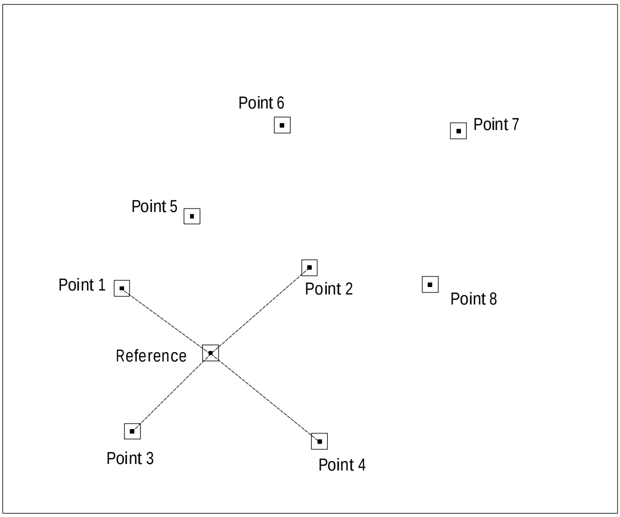
2. Select Baseline Processing mode and process the baselines using "Reference" as the reference and the other points as the rovers. Store the results.

The results for the first days work appear as over:



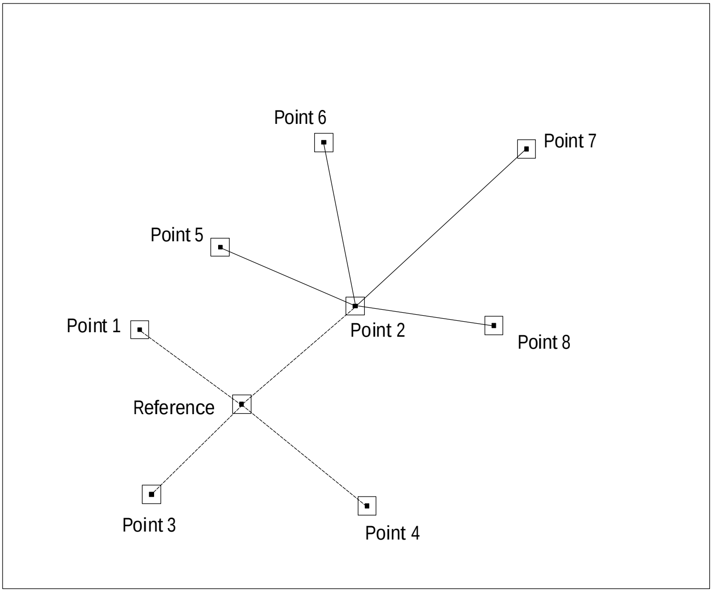
Day 2

The network will be expanded by setting up the reference on Point 2 and the rover on the new stations.



Care is taken to ensure that Point 2 is given exactly the same Point Id. The data is imported in to the same Project.

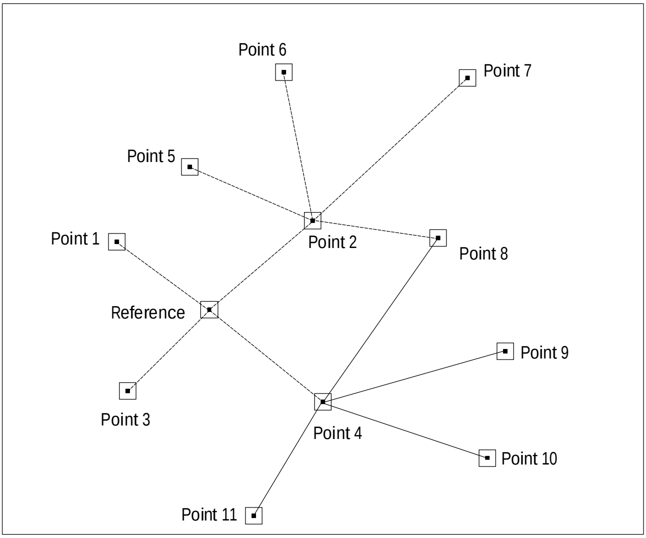
The Baseline data processing between the reference (Point 2) and the rovers can take place immediately. There is no need for a single point calculation since Point 2 was determined in the previous days work. The result is as follows:



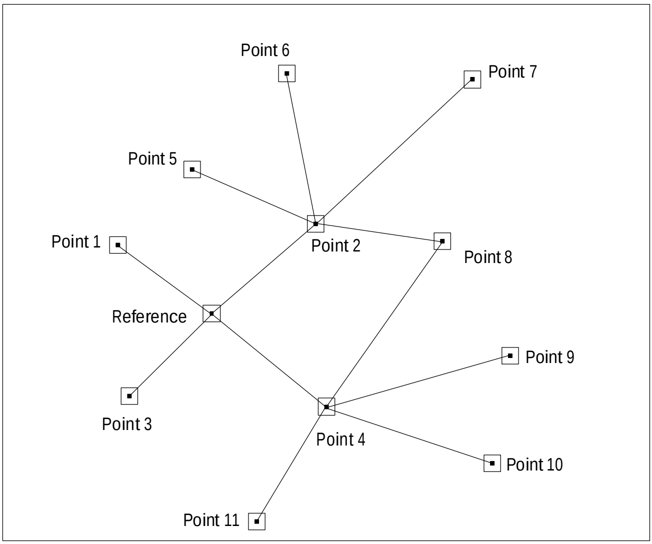
Day 3

On this day, Point 4 was used as the reference. More new points were measured but also Point 8 was measured to provide a check.

Again, no single point processing is necessary for Point 4 (reference point) as this was determined on the first day. The baselines can be computed immediately.



After three days of measurement the following network has been built up:

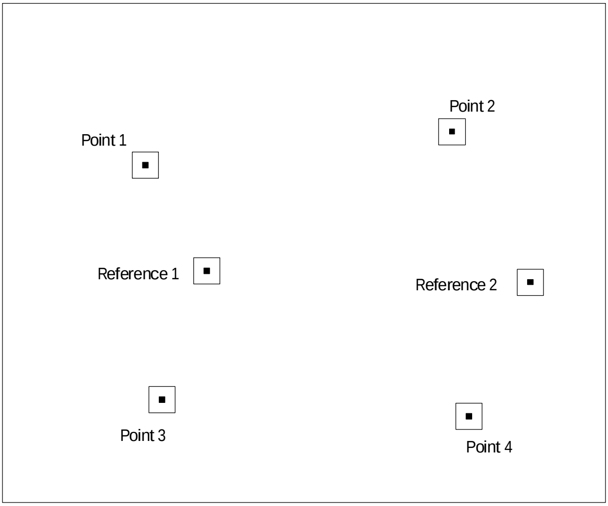


The network can be expanded in this way almost indefinitely, with as many or as few redundant observations as required.

7.1.4 Practical Example 2 - Multiple reference stations

Day 1

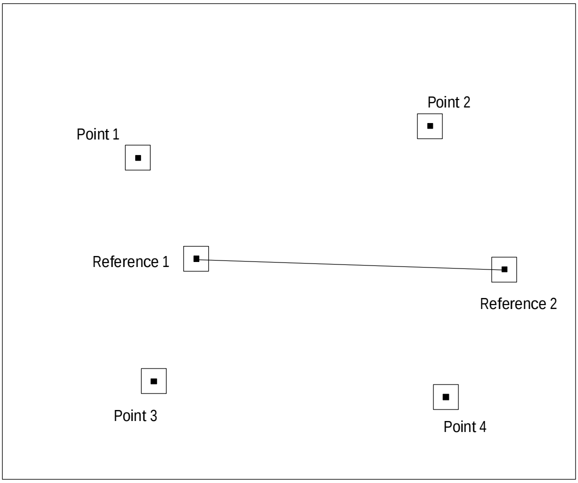
The points below were measured using Rapid Static. Note that two reference stations were used.



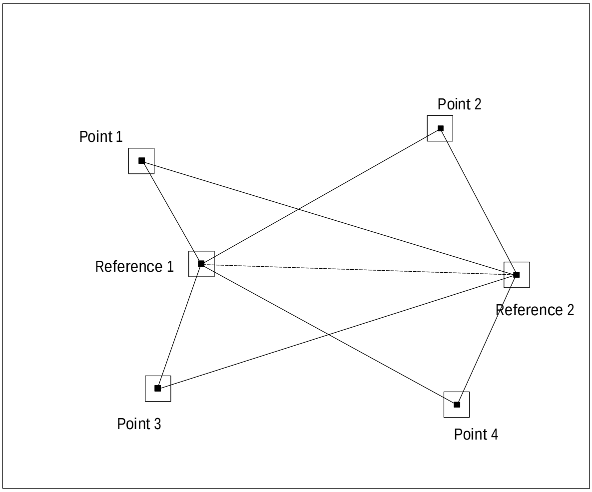
The processing is carried out as follows:

1. Select Single Point Processing mode and process the reference point "Reference 1" as a single point. Store the result.

2. Select Baseline Processing Mode and process the line between "Reference 1" and "Reference 2". "Reference 1" is selected as the reference and "Reference 2" as the rover. Since "Reference 1" was fixed when processed as a single point, "Reference 2" will also now be fixed accurately with respect to it. This then gives the following:

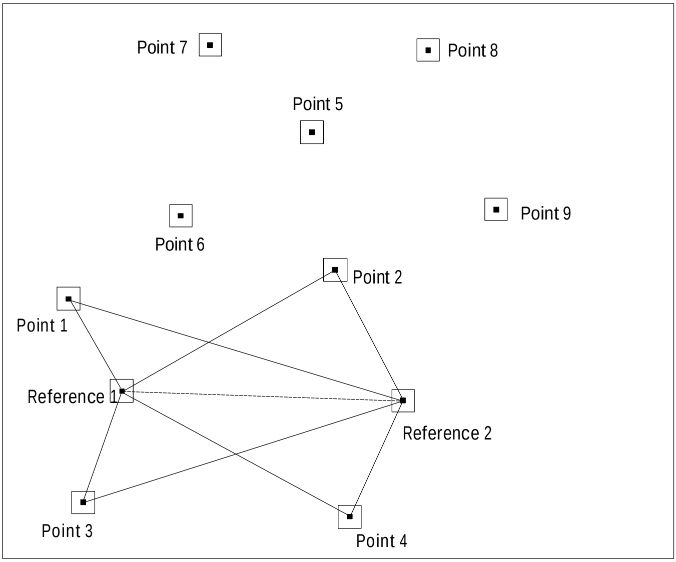


3. Then the baselines from the references to the rovers may be processed. The point "Reference 2" must be de selected as a rover and then reselected as a reference. The point "Reference 1" remains selected as a reference. All the remaining points are then selected as rovers. When the processing is complete and the results stored, the following is achieved:

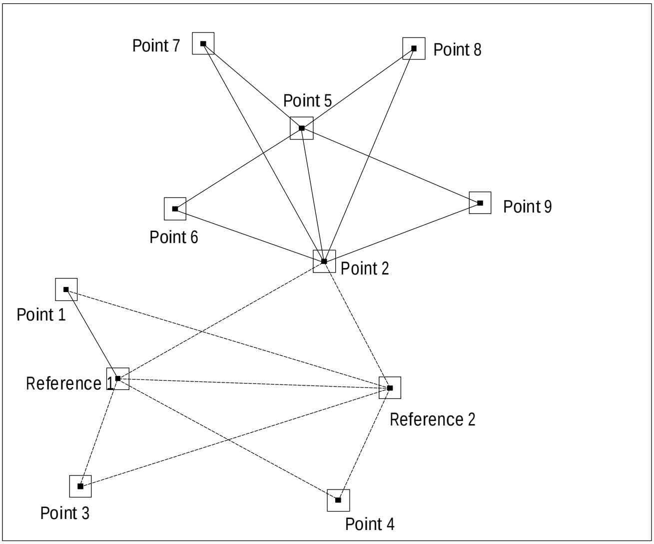


Day 2

On the 2nd day, Point 2 computed on the first day is taken as one reference. The other reference is Point 5, a new unknown point.



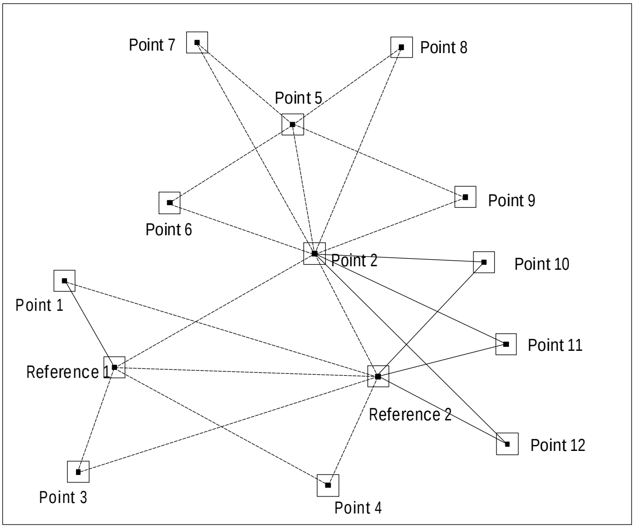
Therefore, since Point 2 has already been computed and is known, the line between Point 2 and Point 5 (the other reference on this day) is computed first.
Then the other rover points are computed relative to Point 2 and Point 5. This gives the following:



Day 3

On the third day, the reference stations were located at Reference 2 and Point 2. These points have both been computed already and therefore the positions are already known. The purpose of using these two points as reference stations is to tie in the new points observed on this day with the existing network.

The baselines from both reference stations to the new rovers may be processed immediately.

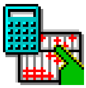


The network can then be expanded further in this manner. The advantage of using two or more reference stations is that it provides redundancy. In other words, a least squares adjustment may be performed on the network.

Further details on the SKI Adjustment component are contained in the Guidelines to Adjustment section of this manual.

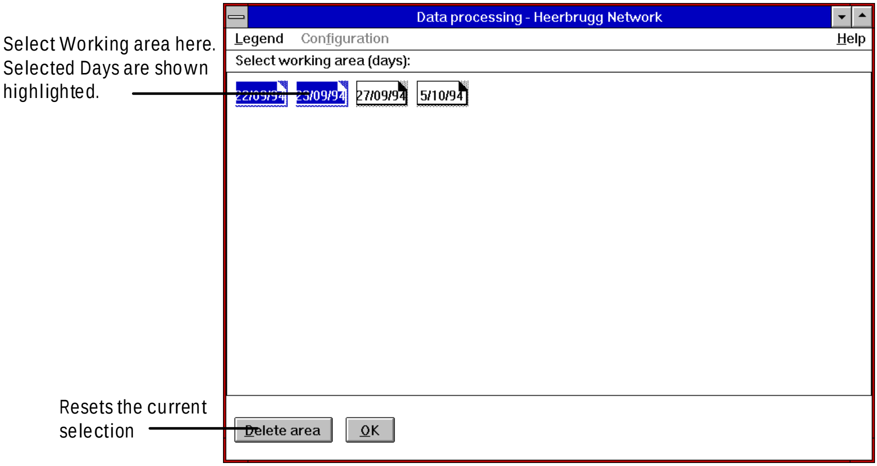
7.2 Baseline selection within SKI

The procedure of baseline selection within SKI is as follows:



1. Set up your Project and Import the data using the respective SKI components. Then start the Data Processing component.

2. Define the working area. The days on which observations were taken are displayed. Select the days which you wish to process together by clicking on the day. If you have taken observations over midnight, two days will appear. Select both days in order that the data is merged. Confirm the selection with **OK**.



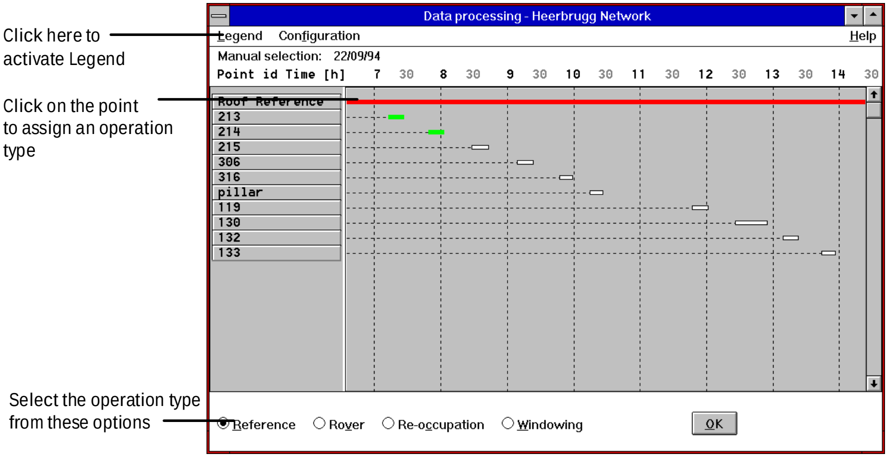
3. Now you must select the days which you wish to assign operation types to. Select one day at a time and assign the operation types for each point on each day.

4. Assigning the operation type can be done either automatically or manually.

For automatic assignment of operation types click on **Auto Select** and select the reference sites by clicking on them from the box that appears. All possible baselines between the chosen reference sites and remaining sites will then be selected for computation. Proceed to step 6.

For manual assignment of operation types click on **Manual**.

5. When **Manual** has been pressed the following window appears:



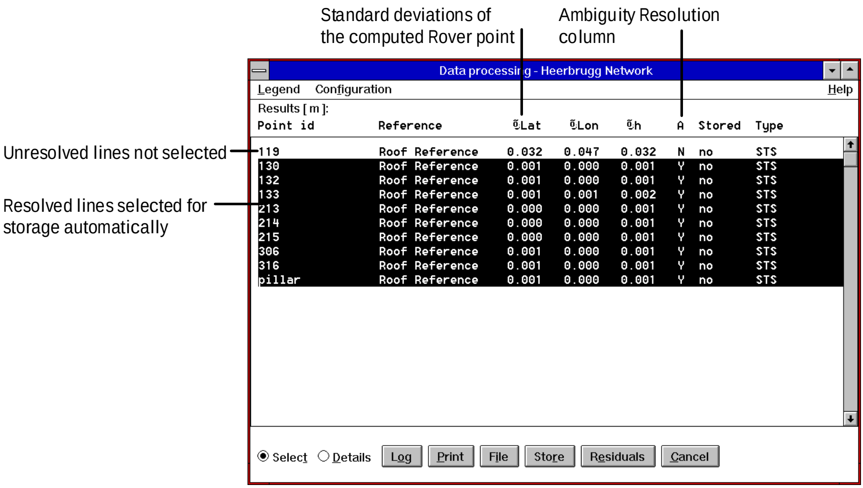
Select the Reference assignment tool from the lower part of the screen and click on the point(s) that you wish to use as a reference station(s). The occupation intervals of the reference station(s) will be shaded grey. Then select the Rover assignment tool and select the point(s) you wish to compute as Rovers. When you are satisfied with your selection click on **OK**.

6. The computation selection window is shown once again. If you wish to select a further day for either automatic or manual operation type assignment you may do so. Otherwise you may now press **Compute** to activate the computation.

7. The computation runs totally automatically with no need for user interaction. When the computation is complete the results panel will be displayed. Further information on the results panel is contained in the next section.

7.3 The Results Panel

When the computation is finished and the Results button pressed, a window similar to the following appears.



All baselines that were computed are displayed together with the standard deviations of the Rover point in metres, whether the ambiguity to the Rover point was resolved or not, whether or not the information has been stored in the SKI database yet and what operation type was used to collect the data.

At the bottom of the screen are two radio buttons, Select and Details. When Select is chosen you may select or deselect lines for storage. Note that lines that have resolved ambiguities are automatically selected for storage.

Details — Details enables you to view further details about each point. After selecting this
the cursor changes to an "i". Click on each individual line to view the coordinates of the Rover point and associated standard deviations.

Log — Produces a logfile of the computation. This may be a summary of the computation or a detailed report of what has taken place during the computation. See section 7.3.2 for further details.

Print — Prints a list containing the selected Point Ids, their associated coordinates (Geodetic or Cartesian), any attached attributes and the variance - covariance matrices. The same information regarding the reference point(s) will be included also.

File — Allows you to save the selected information to an ASCII file. You may store either a point list or the baseline vectors. You may also specify transformation parameters entered/computed in Datum/Map to achieve coordinates in the system of your choice.

Store — Stores the results in the SKI database to enable them to be used in other SKI components.

Residuals — Enables you to compute Residuals of each satellite observation. Refer to section 7.3.3 for further details.

Cancel — Cancels the window.

7.3.1 What does "Ambiguity Resolution" mean

Ambiguity Resolution is the determination of the whole number of cycles between the Satellites and GPS Sensor. This is essential for centimetre level results with short observation times. Further details can be readily found in the many in depth texts that have been written on this subject.

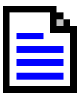
Ambiguities will only be resolved by SKI on baselines of 20 km or less. For longer distances, the Ambiguity resolution becomes unreliable. To achieve good results on baselines longer than 20km you will need to observe for longer periods of time. Note that even then ambiguities will not be resolved even though results are achieved to within the system specifications.

In the Ambiguity Resolution column (A) in the SKI Results window you may view one of the following:

Y - Means that SKI was able to resolve the ambiguity.
Y* - Means that SKI was able to fix the ambiguities but only at a 99.9% confidence level for Rapid static points or 99.99% for kinematic points. Additionally, this will be shown when Stop and Go or Kinematic data has been processed and at the end of the site occupation, less than 5 ambiguities (5 satellites) are fixed or if rms of weight unit > 1. Whenever this result type appears in the result column, the result should be treated with caution.
N - Means that SKI could not resolve the ambiguity.
? - Means that no attempt was made to resolve ambiguity.

If ambiguity resolution was not achieved or if no attempt was made to resolve ambiguity, you may view the Logfile to find the reason for this.

7.3.2 The Results Logfile



The Results Logfile gives you more detailed information about what has taken place during the computation. If there was a problem during computation such as no ambiguity resolution or no attempt was made to resolve ambiguities the reason for this may be determined.

You may display a Summary Logfile or a Full Information Logfile. Default settings for the logfile contents may be configured in Logfile contents... in the Configuration menu.

A Summary Logfile contains the following sections of the Full Information Logfile.

GE_PS Project Settings
GE_PP Processing Parameters
GE_SS Satellite Selection
GE_BO Baseline Overview
GE_IC Initial Coordinates
Baseline Results

If the Full Information Logfile has been chosen, you may select exactly which sections of information you wish to be displayed. A full description of all sections is given below.

General Information: Project Settings

```
########################################################################
#     GE_PS  PROJECT  SETTINGS                                         #
########################################################################

Processing software  :  Leica SKI / Data processing version 2.0-2
General header       :  Leica AG, CH-9435 Heerbrugg
Project name         :  Heerbrugg
Coordinate system    :  WGS84
Time                 :  All results in local time  (GPS +  0.00 hr)
```

The version number of the data processing component of SKI is displayed together with the general header entered in the configuration component and the project name given when the project was created. The coordinate system and selected time frame is also given.

General Information: Processing Parameters

```
##########################################################################
#     GE_PP  PROCESSING  PARAMETERS                                      #
##########################################################################

Cut-off angle (deg)                       :  15
Tropospheric model                        :  Hopfield
Ionospheric model                         :  Computed
Ephemeris                                 :  Broadcast
Data used                                 :  Use Code and Phase
Phase Frequency                           :  L1 + L2
Code Frequency                            :  L2
Limit to resolve ambiguities (km)         :  20
a priori rms (mm)                         :  10
Sampling rate for static (sec)            :  Use all
Phase processing                          :  Automatic
Cycle slip detection                      :  Phase check & loss lock flag
Update rate for kinematic (epoch)         :  1
Minimum time to fix amb - L1 only (min)   :  9
```

The processing parameters used for the computation run as defined in *Configuration / Parameters*... are listed.

General Information: Satellite Selection

```
##########################################################################
#     GE_SS  SATELLITE  SELECTION                                        #
##########################################################################

Manually disabled satellites  :  None
```

This indicates which satellites (if any) were omitted for use in data processing.

General Information: Baseline Overview

```
###########################################################################
#     GE_BO  BASELINE  OVERVIEW                                           #
###########################################################################

Total no of baselines computed : 5

BL  CH  Rover             Reference        First common ep    Amb Frq Obs
id  id                                                                Mod

1   1   P1                34193            25/11/95 15:55:00   Y  1+5 STS
2   2   P2                34193            25/11/95 16:04:45   Y  1+5 STS
3   3   P3                34193            25/11/95 15:38:15   Y  1+5 STS
4   4   P4                34193            25/11/95 15:18:00   Y  1+5 STS
```

The total number of baselines used in that computation run are first listed.

`BL id` All baselines are sequentially numbered. This number is called the baseline identifier and is used later on as reference for the baseline specific information.

`CH id` The chain identifier indicating to which chain a baseline belongs (e.g., baselines of a stop and go run belong to the same chain).

`Rover` Point id of roving receiver.

`Reference` Point id of site selected as a reference.

`First common ep` Date and time for the first common epoch of the baseline.

`Amb` Ambiguity indicator:
1) Y means ambiguities have been resolved
2) Y* means ambiguities resolved but the result should be treated with caution.
3) N means not resolved.

`Frq` The frequencies for which ambiguities have been resolved.
1 = ambiguities for L1
2 = ambiguities for L2
3 = ambiguities for L3 (ionosphere free linear combination)
5 = ambiguities for L5 (wide laning)

(If the ambiguities for L1+L5 are known, then also the ambiguities of L2 are known).

`Obs Mod` Type of observation used in the Controller.

STS static or rapid static
SGS stop and go
KIS kinematic
KOF kinematic on the fly

General Information: Initial Coordinates

```
########################################################################
#     GE_IC  INITIAL  COORDINATES                                      #
########################################################################

Reference :

Point id : 34193
   X    4216398.9046  m      Y   2335816.6357  m    Z   4162956.8701  m
 Lat  41 00 21.96518 N    Lon  28 59  8.67210 E    h        34.0021  m

Rover :

Point id : P1
   X    4213482.7907  m      Y   2332921.0627  m    Z   4167613.3849  m
 Lat  41 03 39.97140 N    Lon  28 58 20.71578 E    h       108.4926  m

Point id : P2
   X    4213481.6182  m      Y   2332922.7668  m    Z   4167613.5750  m
 Lat  41 03 39.98031 N    Lon  28 58 20.80396 E    h       108.4664  m

Point id : P3
   X    4213658.0167  m      Y   2332881.8646  m    Z   4167463.1265  m
 Lat  41 03 33.43895 N    Lon  28 58 15.61222 E    h       111.0684  m

Point id : P4
   X    4213658.1125  m      Y   2332884.9042  m    Z   4167461.2576  m
 Lat  41 03 33.36014 N    Lon  28 58 15.72411 E    h       111.0143  m
```

For each computation run — first for the reference points and then for the roving points — the initial coordinates (coordinate values used to start computation) are given in Cartesian and geodetic coordinates.

General Information: Ionospheric Models

This information appears only if a computed ionospheric model has been selected in Configuration/Parameters

```
################################################################################
#     GE_C1  IONOSPHERIC MODELS                                                #
################################################################################

Point id : 000001Dach
XSOFT Ionosphere Program
-------------------------------------------------------------------------
ORIGIN OF DEVELOPMENT: TIME (UT)  (Y M D H)    : 1994  9 22   6.5791669
                       LATITUDE   (DEGREES)    :   47.4089
                       LONGITUDE  (DEGREES)    :    9.6174
APPLICABILITY          FROM EPOCH              : 1994  9 22   6.5791669
                       TO EPOCH                : 1994  9 22  14.4000006
COEFFICIENTS:
DEG. LAT   DEG. TIME  COEFFICIENT        RMS
    0          0        .58883567E+00    .41963973E-02
    0          1        .40332931E+00    .30327740E-02
    0          2      -.80695587E-01    .79294283E-03
    1          0        .80349026E-01    .42859951E-02
    1          1      -.88277162E-01    .15577817E-02
```

The Point Id for which the ionospheric model has been computed is displayed followed by the time, Latitude and Longitude when the observations were taken. Then the time period for which the model is applicable is shown.
Then the first 5 coefficients of the electron density E of the ionospheric model that has been calculated are displayed.

Start of a new Chain

```
CH.1  =======================================  NEW  STATIC  CHAIN  =====
```

Whenever a new chain starts it is indicated by its chain id.

Baseline Information: Header

```
################################################################################
#     BL.1    P1               34193            25/11/95 15:55:00    #
################################################################################
```

The header information of each baseline contains:
- baseline id
- point id of rover site
- point id of reference site
- date and time of first common epoch

```
BL_SE.1    START / END  (COMMON)  EPOCHS
----------------------------------------
  25/11/95 15:55:00     to  25/11/95 16:02:00
```

The start and end date and time are listed for the common epochs of the baseline.

Baseline Information: Operation Information

```
BL_OI.1    OPERATION  INFORMATION
---------------------------------
                           Rover                      Reference
Point id                   P1                         34193
Sensor/Controller id       219   /97939               1890 /97936
Operation mode             STS                        STS
Observation rate (s)       15.0                       15.0
Ht reading/Ant offset (m)  1.178  /0.389              0.978  /0.441
Eccentricity E/N/H (m)     0.000   /0.000   /0.000    0.000   /0.000   /0.000
```

All baseline related operation information gathered in the field are listed for the rover and reference sites. In case of reoccupation some of the information will be repeated for each occupation.

Baseline Information: Satellite Information

```
BL_SI.1    SATELLITE  INFORMATION
---------------------------------
 SV id    L1 phase  L2 phase  L1 code  L2 code
     2        29        29        0        29
     7        29        29        0        29
    16        29        29        0        29
    26        29        29        0        29
    27        29        29        0        29
```

For each frequency and observation type the number of epochs per satellite used for the baseline computation are listed.

`SV id`	Satellite number
`L1 phase`	on L1 frequency: carrier phase measurements
`L2 phase`	on L2 frequency: carrier phase measurements, S indicates measurements taken via squaring.
`L1 code`	on L1 frequency: code (P–code) measurements
`L2 code`	on L2 frequency: code (P-code) measurements

Baseline Information: Elevation Azimuth

```
BL_EA.1   ELEVATION / AZIMUTH
-----------------------------

sat id:                2      26      27       7      16
hh:mm:ss PDOP GDOP
15:55:00  4.8  5.8  73/ 53  52/306  41/ 78  32/145  25/218
15:55:15  4.8  5.8  73/ 53  52/306  41/ 78  32/145  24/218
15:55:30  4.8  5.8  72/ 53  52/306  41/ 78  32/145  24/218
15:55:45  4.8  5.8  72/ 53  52/306  41/ 78  32/145  24/218
15:56:00  4.8  5.8  72/ 52  52/306  41/ 79  32/145  24/218
15:56:15  4.8  5.8  72/ 52  52/306  40/ 79  32/145  24/218
15:56:30  4.8  5.8  72/ 52  52/306  40/ 79  32/145  24/217
15:56:45  4.8  5.8  72/ 52  52/306  40/ 79  33/145  24/217
```

The PDOP, GDOP of the satellite constellation and the elevation and azimuth of each satellite are shown for every epoch recorded. Note In the above example, only the first 8 observations are shown. Obviously, for stations observed for long periods of time, this list can be quite sizable.

Baseline Information: Processing Information

```
BL_PI.1    PROCESSING  INFORMATION
----------------------------------


General Information
-------------------
Reference receiver type                  : SR399
Reference antenna type                   : Internal
Rover receiver type                      : SR399
Rover antenna type                       : Internal
Total number of used measurements        :        290
Total number of ambiguities              :          8
Reference satellite L1                   :          2
Reference satellite L2                   :          2
Root mean square unit weight             :     0.3153
```

Reference/Rover receiver type is the type of receiver used at the Reference/Rover

Reference/Rover antenna type is the type of antenna used at the Reference/Rover.

Total number of used measurements is the total number of phase measurements taken on L1 and L2 used in the computation.

Total number of ambiguities is the total number of ambiguities that need to be solved in the computation. This is normally two for each satellite for which observations were used.

Reference satellite L1 and Reference satellite L2 refer to the satellite taken as the reference for the computation. This is normally the highest satellite.

Root mean square unit weight gives the standard deviation of the solution before the ambiguities are fixed.

Baseline Information: FARA Statistics

```
BL_FS.1    FARA  STATISTICS
---------------------------


-----------------------------------------------------------------------
Ambiguity Resolution successful at        :                16:02:00

Search Statistic
----------------
  set#      rms         ratio
   1       0.0022       1.0000
   2       0.0077       3.4496

Ambiguity Values
----------------
set# 26/L1 26/L2 27/L1 27/L2  7/L1  7/L2 16/L1 16/L2
   1   -22    85     2    21   -11    16   -12    51
   2   -31    84     7    22   -11    16   -25    50

Statistical Summary
-------------------
rms a priori         :   10.0 [mm]   rms float            :    1.8 [mm]
Test (rms float < rms a priori)                           :      passed
Error prob. alpha    :   5.000 [%]

rms fix 1            :    2.2 [mm]
Test (rms fix 1 < rms a priori)                           :      passed
Error prob. alpha    :   5.000 [%]

Test (rms fix 1 < rms fix 2)                              :      passed
Error prob. alpha    :   0.001 [%]
```

This part contains characteristic values for the fast ambiguity resolution approach.

`Ambiguity Resolution successful at` The time during the measurements at which it was possible to resolve the ambiguity is given.

`Search Statistic` The rms of the most likely and the second most likely solutions are given. The ratio of these values to the first value is displayed. When the ambiguity is resolved, the ratio of set 2 should be rather higher than 1.000.

`Ambiguity Values` The ambiguity values are displayed for each satellite for the most likely and the second most likely solutions. These are the number of ambiguities estimated for each satellite and frequency for the first two solutions

`Statistical Summary` This displays the various test criteria for fast ambiguity resolution.

`rms a priori` Limit for phase noise rms. The value can be changed in the processing parameter list.

`rms float` Actual rms value before fixing ambiguities.

`rms fix 1` rms value after fixing ambiguities for the best suitable ambiguity set.

`rms fix 2` rms value for the second best suitable ambiguity set.

`error prob.alpha` defines the significance level of 100%–alpha on which the hypothesis test is carried out.

A condition to enter FARA is that in case of dual frequency measurements a wide laning solution has been possible. Then the three hypotheses on their specified significance level are tested:

1) rms float < rms a priori
2) rms fix 1 < rms a priori
3) rms fix 1 < rms fix 2

Only if all of these tests have been successfully passed is the ambiguity resolution accepted as successful. These hypotheses are also used for single frequency measurements.

If the first test (rms float < rms a priori) fails the limit of rms a priori can be set to a higher value. However this should be done with care — and for small observation intervals (approximately 10 to 15 minutes) it is not a recommended procedure. However for longer distances, with observation periods of 1 hour or more, there is no danger in even doubling the value (ionospheric influence).

If the last test fails it must be accepted that you will not be able to resolve the ambiguities. This is because from a statistical point of view the two possible ambiguity sets are equally suitable.

Baseline Information: Cycle Slip Information

```
BL_CS.1    CYCLE  SLIP  INFORMATION
-----------------------------------

Total no of cycle slips : 0
```

If cycle slips occur they are corrected within SKI. The total number of cycle slips is given and for each individual cycle the following information is listed:

`Time`	date and time of epoch
`time from start`	the time in seconds that elapsed since the first common epoch
`SV`	satellite number
`freq`	carrier on which the cycle slip occurred 1: L1 carrier 2: L2 carrier
`slip value`	integer number of slip
`fraction`	fractional part
`ucs`	Unflagged cycle slip. The cycle slip was not flagged in the data but was found by the software.
`ria`	Reinitialised ambiguity. The cycle slip could not be fixed by the software and the ambiguity search was reinitialised afterwards.

Baseline Information: Final Coordinates

```
BL_FC.1    FINAL  COORDINATES
-----------------------------

Rov:000213  Ref:000001 Dach  Amb:Y* Proc: L1+L2 phase 18.02.92 10:46:30
Cartesian :
   X   4264664.3038  m      Y    722228.4239  m    Z   4672307.2509  m
  dX       795.2432  m     dY      -282.9041  m   dZ      -702.3717  m
  sX         0.0014  m     sY         0.0004  m   sZ         0.0010  m
Geodetic :
 Lat  47 23 59.35701 N    Lon   9 36 42.99665 E    h       463.6374  m
dLat        32.95388     dLon        19.63693     dh       -18.3550  m
sLat         0.0006  m   sLon         0.0004  m   sh         0.0016  m
Distance :
Slope      1098.0767  m    sSlope   0.0006  m
```

The final coordinates as well as the vector components and standard deviations are given in Cartesian (X, Y, Z) and geodetic (lat, lon, h) coordinate systems. The slope distance and its standard deviation are derived from them. The standard deviation is found by applying the variance–covariance law to the fully populated variance–covariance matrix or the space vector.

Baseline Information: Variance-Covariance Matrix

```
BL_VC.1    VARIANCE-COVARIANCE  MATRIX
--------------------------------------
a posteriori rms :     0.0023
Co-factor matrix (upper triangle [m*m]) :
             qx                qy                qz
 qx   +3.4153867E-001  +2.6724979E-002  +1.9766039E-001
 qy                    +2.6603278E-002  +6.2533421E-003
 qz                                     +1.6932274E-001
```

Note that in this part it is not the actual variance–covariance matrix that is given. Rather the information is split into two parts as it is obtained from the least squares adjustment thus resulting in the r.m.s. a posteriori and the co–factor matrix (which is the inverse of the normal equation matrix of the least squares adjustment).

To obtain the variance–covariance matrix multiply each element of the co–factor matrix with the squared a posteriori value.

From this point onwards the logfile gives you the same information for the remaining baselines.

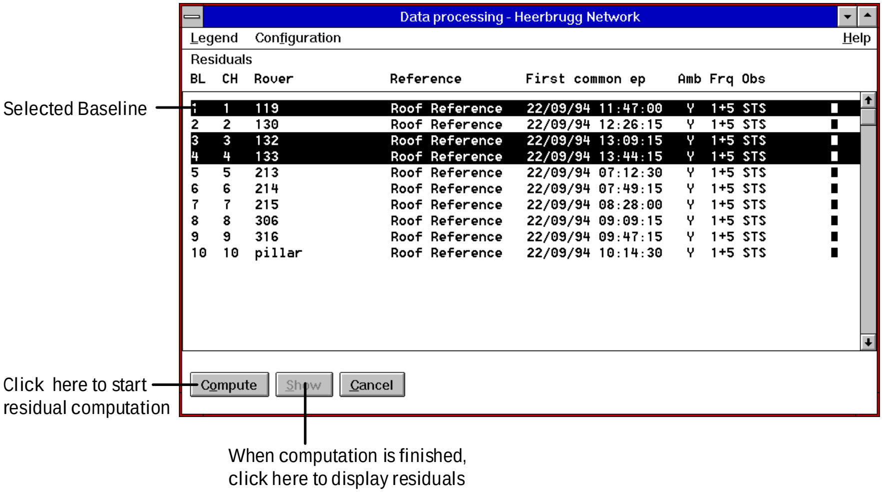
7.3.3 Computing Residuals

You may compute the residuals of each individual measurement to each satellite.

Press the Residuals button from the results window.

A panel will appear containing all the computed baselines. Select the baselines for which you wish to compute residuals by clicking on them.

When you are satisfied with the selection click on the **Compute** button.



When the computation is complete the **Show** button will become active. Click on **Show** to display the computed residuals.
When the computation is complete the **Show** button will become active. Click on **Show** to display the computed residuals.

You will then be prompted to select the type of residuals you wish to display. Make your selection and click on **OK**.

7.3.3.1 The Residual table

When the table of residuals is displayed the Project settings and Processing Parameters and Satellite Selection are first given. (See section 7.3.2).

The computed residuals are then displayed, (a shortened example is given below). The range residual to each satellite observed at each epoch is displayed.

```
DP_BL.    1   L2 PHASE RESIDUALS
--------------------------------------

date :    95-11-25  (yy-mm-dd)
sat id :           R 2      27      16      19       7
hh:mm:ss GDOP
15:38:15  4.1      .000    .000    .000    .000    .000
15:38:30  4.1      .002    .001   -.004   -.003   -.006
15:38:45  4.1      .001    .003    .002   -.007   -.010
15:39:00  4.1      .001    .003   -.001   -.006   -.010
15:39:15  4.1      .001    .004   -.001   -.002   -.011
```

The date on which the measurements were taken is displayed in year, month, day. Below this is the satellite id row showing which satellites were observed. An R before a satellite means this was used as the reference satellite. Below this are the two headers for the time of each observation and the GDOP value at this time.

Then the main body of information is given on the subsequent lines. At each epoch, the time, GDOP and residual (in metres) to each satellite is given.

Note that the example given above is shortened. Depending on the length of time of observations, this list can be lengthy.

7.4 What to do if A=N?

Occasionally for various reasons SKI may not be able to resolve the ambiguities for certain points. If this is the case the ambiguity (**A**) column in the display panel will indicate No (**N**).

The basic requirements for ambiguities to be resolved (A=Y) are as follows:

1. rms float is less than a priori rms

and

2. rms fix 1 is less than a priori rms (rms fix 1 will usually be slightly higher than rms float)

and

3. rms fix 1 is significantly less than rms fix 2

and

4. the baseline length is less than the limitation value.

All of this information is contained in the logfile in the FARA statistics section.

Using some of the following techniques it may be possible to recompute a baseline and resolve ambiguities.

7.4.1 Unresolved Baselines above the limitation value

For baselines longer than the limitation value, (default 20km), the results will meet the accuracy specifications provided that the observation period was sufficiently long for the length of line. It is possible to increase the limitation value above 20km in order to try to resolve the ambiguity but there is little point in attempting this for long lines. Some experience in data processing is required before experimenting with different limitation values.

7.4.2 Unresolved Baselines below the limitation value

There may be one or a combination of several factors when baselines shorter than the limitation value cannot be resolved by SKI. The following sections all refer to baselines that are below the limitation value.

The most common reasons for the failure of ambiguity resolution are:

- Poor satellite geometry (GDOP).
- Observation times too short.
- Noisy, incomplete or interrupted data.

7.4.2.1 The reference point

For successful ambiguity resolution, good WGS84 coordinates are needed for the reference (fixed) point of the baseline. Poor initial coordinates may cause the ambiguity resolution to fail. If necessary, compute a single point position for the reference point before computing the baseline.

7.4.2.2 Start/End Common Epochs

Check this section of the logfile to find out the length of time over which observations were recorded at the reference and at the rover. Is it long enough for the baseline length ?

```
BL_SE.1    START / END (COMMON) EPOCHS
--------------------------------------
  25/11/95 15:55:00     to  25/11/95 16:02:00
```

7.4.2.3 Satellite Information

This section gives you the number of observations taken to each satellite for each part of the satellite signal.

Ideally, for each satellite, the number of observations of each part of the signal should be the same. In practice this may not happen. Usually, the Sensor acquires the L1 signal before the L2. Therefore it is not unusual to see a slight difference in the number of L1 and L2 observations from each satellite.

Be wary if the Sensor has only taken a couple of observations to a satellite (it came into view just as you were shutting down the equipment), this could also cause problems. Try deleting the satellite and recomputing.

Additionally, look out for large amounts of L2 observations missing for any particular satellite(s). Try noting down the number of the satellite on which this occurred. Then go back to data processing, remove the particular satellite in Configuration/Satellite Selection and re-compute the baseline. Remember however that you must observe at least four satellites for the duration of the station occupation.

Example

```
BL_SI.1    SATELLITE  INFORMATION
---------------------------------
 SV id   L1 phase  L2 phase  L1 code  L2 code
     2        29        29        0       29
     7        29         0        0        0
    16        29        29        0       29
    26        29        29        0       29
    27        29         3        0       29
```

In the above example, satellite 7 has no measurements on L2 carrier phase or code. Additionally, only 3 L2 phase measurements were taken to satellite 27. This may give problems during data processing.

7.4.2.4 Elevation/Azimuth

The Elevation/Azimuth section of the logfile shows the GDOP and the elevation and azimuth for each satellite observed at each epoch. Ideally there should be 5 or more satellites and the GDOP should be less than or equal to 8.

When a satellite is observed intermittently, it will appear and disappear from the Azimuth/Elevation list. This satellite could give problems.

Try windowing out the period of time when the satellite in question gave problems by using the windowing tool during Manual Selection. Remember that you require a certain amount of time for successful ambiguity resolution depending on the baseline length, satellite constellation etc.

Alternatively, remove the satellite in question from the computation by de selecting it in Configuration/Satellite selection and re-computing. Remember however that you must observe at least four satellites for the duration of the station occupation and that GDOP must be less than or equal to 8. Deleting satellites will increase the GDOP value.

Example

```
BL_EA.1   ELEVATION / AZIMUTH
-----------------------------

sat id:                6      16      18       1       9      24
hh:mm:ss PDOP GDOP
10:46:30  5.9  6.5  77/325  37/ 62  32/172  42/240  55/ 98  18/ 67
10:47:00  5.9  6.5  78/325  37/ 61  32/172  43/240  55/ 98  18/ 68
10:47:15  5.8  6.4  78/325  36/ 61  33/172  44/241  54/ 98  18/ 68
sat id:                6      16      18       1       9
hh:mm:ss PDOP GDOP
10:47:30  8.8  7.0  78/325  36/ 61  33/172  44/241  54/ 99
10:48:45  8.8  7.0  78/326  36/ 61  33/172  44/241  54/ 99
sat id:                6      16      18       1       9      24
hh:mm:ss PDOP GDOP
10:48:00  5.9  6.5  78/326  36/ 61  33/173  44/241  54/ 99  18/ 68
sat id:                6      16      18       1       9
hh:mm:ss PDOP GDOP
10:47:15  8.8  7.0  78/325  36/ 61  33/172  44/241  54/ 99
10:48:30  8.8  7.0  78/326  36/ 61  33/172  44/241  54/ 99
```

Satellite 24 is observed only intermittently, and may possibly give problems.

7.4.2.5 FARA Statistics

Ambiguity resolution will not be attempted if the rms float and/or the rms fix 1 are larger than the a priori rms. This information is contained in the FARA Summary section of the logfile.

The default setting for the a priori rms is 10mm. You can increase the a priori rms and recompute the baseline but please note the following:

- For baselines with up to about 15 minutes observation time, increasing the a priori rms to more than 10 mm is NOT advisable as this could lead to a weak solution being accepted.
- For baselines with longer observation times (at least 30 mins), you can usually set the a priori rms to a value higher than 10mm and recompute without undue risk.
- It is advisable to have some experience in data processing before experimenting with a priori rms settings.

7.4.2.6 Cycle Slip Information

The Cycle Slip Information section of the Logfile notifies you of how many cycle slips occurred during the occupation of the station, when they occurred and on which satellite(s). If there are many cycle slips on one particular satellite, try removing it from the computation and re-compute. Remember however that you must observe at least four satellites for the duration of the station occupation.

Alternatively, if the cycle slips occur at the beginning or end of observations try windowing out the period of time when the satellite in question gave problems by using the windowing tool during Manual Selection. Remember that you require a certain amount of time for successful ambiguity resolution depending on the baseline length, satellite constellation etc.

7.4.2.7 Residuals

The residuals can be computed and viewed. When viewing the L2 phase residuals the values should be in the millimetre range. If, for long periods of time this is not the case, it may indicate where a problem lies. As suggested previously, try windowing out the period of time when the satellite in question gave problems by using the windowing tool during Manual Selection. Remember that you require a certain amount of time for successful ambiguity resolution depending on the baseline length, satellite constellation etc.

Alternatively, remove the satellite in question from the computation by de selecting it in Configuration/Satellite selection and re-computing. Remember however that you must observe at least four satellites for the duration of the station occupation and that GDOP should be less than or equal to 8.

7.5 Data processing strategy - Useful Hints

The following section contains some hints and tips which may be useful during data processing.

7.5.1 The first Reference Point

As explained above, it is very important that the WGS84 coordinates of ONE point in the network are to within 10-20m.

This point is then used as the "origin" of the network. The network should be computed out from this point in such a way that all point used as references for baseline computations are connected directly or indirectly to this point. There are several advantages in computing a network in this way:

- Every reference point of every baseline will be based on the "origin". Thus the network will be homogenous and the WGS84 coordinates of reference points will be to the accuracy required.

- The mean coordinates will be stored for any point that is computed from two or more baselines. Agreement between fixes can be checked immediately by using the **Mean** function in the View/Edit component.

- A network that has been computed carefully and logically in this way will be easy to handle in Adjustment as it is very unlikely that there will be any anomalies.

- For many applications, it will not even be necessary to adjust a small network that has been computed carefully and logically in this way.

7.5.2 Baselines of differing lengths

If baselines of greatly differing lengths have to be computed, it is best not to include them in the same processing run.

- Use one or more computation runs for long baselines that exceed the limitation value.

- Use one or more computation runs for short baselines that are within the limitation value.

7.5.3 Selecting the Processing Mode

As a general rule, it is always best to use the "Baseline" processing mode.

The Automated Processing Mode is a special mode and should only normally be used if input for a session adjustment is required. Refer to Help for further information.

7.5.4 Ionospheric model

For baselines above the limitation value, an ionosphere free L3 solution is computed.

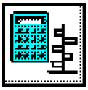
For baselines below the limitation value, the standard ionospheric model (system default), is normally used. The computed ionospheric model can be selected if there are at least 45 minutes of observations at the reference receiver for each baseline.

7.5.5 Processing different types of measurements

Where Static, Rapid Static, Stop and Go or Kinematic measurements are combined in the same Project, compute the network of Static and Rapid Static baselines before the Stop and Go, Kinematic or AROF on-the-fly chains. It is best to compute Stop and Go, Kinematic and AROF chains separately.

SECTION 3 - Guidelines to Adjustment

8 Guidelines to Adjustment - Introduction



This section of the manual deals with how to go about using the Adjustment component of SKI and how to treat results obtained from Adjustment after computation.

8.1 Purpose of Adjustment

The purpose of Adjustment is to calculate the best estimates for all points contained in a network. It can be thought of as a rigorous meaning process where the different quality of each measurement is taken into account. If for example point A is measured from three other points, there will be three different sets of coordinates for point A. The average coordinate values are easy to find for that single point, but if it is connected to other points within a network, it will also affect the position of those points to which it is connected.

Adjustment performs what is known as a least squares adjustment on complete GPS networks, that is it 'averages out' complete GPS networks in a rigorous manner. The other main purpose for performing a least squares adjustment is to detect any points that do not fit homogeneously into the network. Such points are known as outliers.

8.2 General Procedure

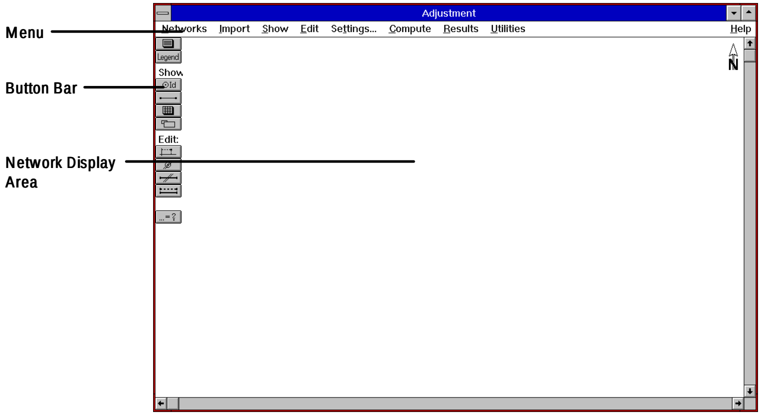
The procedure in the majority of cases will be as follows:

1. Import the processed network from the SKI Project.
2. Compute a free adjustment using the default settings.
3. Identify any outliers.
4. Try to omit any suspect observations.
5. If tying in to an existing network, constrain the common points as fixed.
6. Recompute the network and export to Datum and Map.

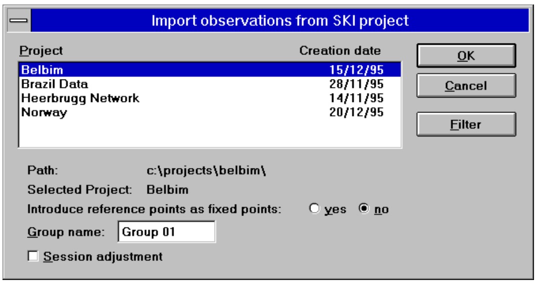
It is suggested that the adjustment of large networks are split up and adjusted in smaller groups in a logical fashion. If you are importing, processing and adjusting data recorded over several days, it may be wise to adjust each days observations separately to find outliers and build up the network in a methodical way.

8.3 Importing the Network

The Adjustment component is started by selecting Adjustment from the SKI Main Menu. The following window will be displayed:



No network information is present upon which to work at the moment. To import processed GPS measurements from SKI, select Import and SKI project. The following window will appear:



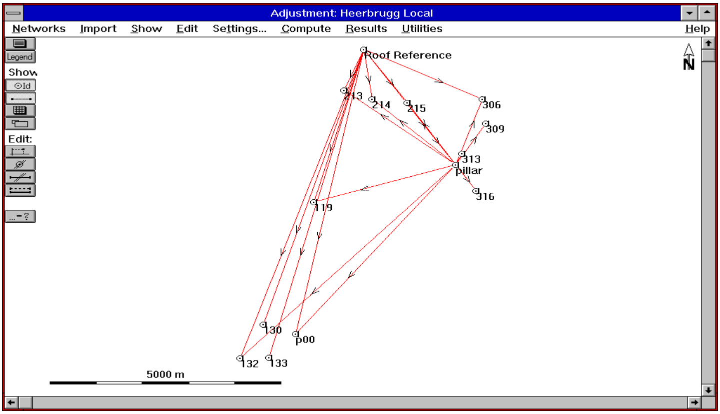
Select the SKI project that you wish to adjust. Accept the default settings in order that a free (unconstrained) adjustment may be carried out. Click on OK.

The network will be imported. Note that the network will be split up into groups of 20 observations. The group numbering is automatic.

8.4 Working on the Network

The Adjustment component has a user interface very similar to the View/Edit component. Many commands may be executed either by using the button bar to the left of the screen or via the menus situated towards the top of the screen.

After importing the network, save it by selecting Networks and then Save. This means that in future, when you come to work on the Network you can simply open it from the Networks menu.



8.5 The Adjustment Process

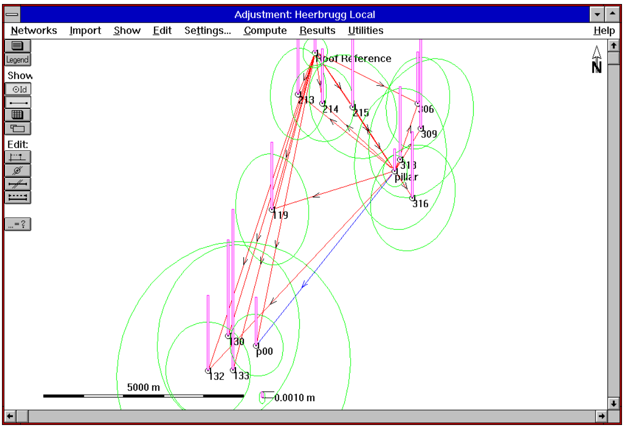
A suggested process is given below that will apply to most users, most of the time.

8.5.1 The Free Adjustment

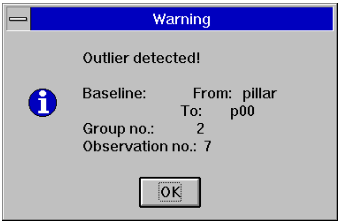
As explained earlier, the first adjustment that is normally performed is a totally free adjustment to try to locate any outliers or observations that are not homogenous with the rest of the network. A free adjustment means that no points in the network are held fixed.

After importing the data you may perform the free adjustment straight away by either clicking on the Compute button or by selecting Compute from the menu.

The following screen will appear showing the error ellipses and height bars. These error ellipses and height bars are calculated from the variance/covariance matrix for each point, that is they give an indication of the accuracy of each point.



If an outlier is detected, a warning box will be displayed.



The outlier displayed is the largest or most likely cause of error in the network. This does not mean that there is definitely an error in the network. The Results logfile must now be examined and the likelihood of an error assessed.

8.5.1.1 Explanation of the Results Logfile

The first section of the Adjustment results logfile contains an overview of the adjustment.

```
Adjustment type           :  Free
Number of observations    :  84
Number of unknowns        :  42
Degrees of freedom        :  45
Datum defect              :  3
Number of groups          :  2

Sigma a priori      :      0.0008 [m]
Sigma a posteriori :      0.0140 [m]
```

`Adjustment Type`	: Type of adjustment performed. `Free` = no points were held fixed. `Minimal constrained` = one point held fixed. `Constrained` = two or more points held fixed.
`Number of observations`	: No. of observations used in the adjustment. This is number of baselines x 3 (vector components of each baseline).
`Number of unknowns`	: No. of non-fixed points x 3 (lat, lon and height component of each point).
`Degrees of Freedom`	: No.obs - (No. unknowns-Datum Defect). Used in computing sigma a posteriori.

`Datum defect`	: Compensation value used when a free adjustment is performed. Value is either 3 (Datum defect used, free adjustment performed) or 0 (Datum defect not used, minimal constrained or constrained adjustment performed).
`Number of groups`	: Automatic separation of observations for data management purposes. Up to 20 observations included in each group.
`Sigma a priori`	: Sigma value prior to computation estimated from GPS co-variance matrices
`Sigma a posteriori`	: Sigma value calculated from adjusted coordinates. Adjusts for uncertainty of the a priori value and is applied to scale the Standard Deviations of the adjusted points.

The next section contains information concerning the vectors of all the observations used in the adjustment computation. A shortened example is given.

```
Vectors
-------

From point       To point         Obs no.      DX            DY            DZ
----------------------------------------------------------------------------
Roof Reference   119              01_001     29
60.867     -574.485    -2616.093
Roof Reference   119              01_002     2960.865      -574.478    -2616.105
pillar          119              01_003     1186.421     -2873.540     -642.992
Roof Reference  130              01_004     5378.755     -1262.193    -4697.814
Roof Reference  132              01_005     6090.263     -1641.509    -5282.970
pillar          132              01_006     4315.793     -3940.572    -3309.848
Roof Reference  133              01_007     5970.220     -1029.733    -5265.909
Roof Reference  213              01_008      795.226      -282.904     -702.389
```

`From point`	:Start point of vector (GPS reference point)
`To Point`	:End point of vector (Computed GPS point)
`Obs no.`	: Observation number assigned by adjustment.
`DX`	:Vector component along x axis of Cartesian WGS84 system
`DY`	:Vector component along y axis of Cartesian WGS84 system
`DZ`	:Vector component along z axis of Cartesian WGS84 system

The Geodetic residuals are displayed next. These are in a graphical form which makes it easy to spot observations with the largest residuals. A shortened example is given.

```
Geodetic Residuals
------------------

Point id        Obs no.
(from/to)                                                       Scale [mm]
                        -27     -18     -9       0       9      18      27
                         +-------+-------+-------+-------+-------+-------+-------+
Roof Reference   01_001                      ----|
119                                              |-------
                                              ---|
Roof Reference   01_002                          |-
119                                              |-
                                                 |-----
pillar           01_003                          |--
119                                        ------|
                                        ---------|
Roof Reference   01_004                          |
130                                              |
                                                 |
Roof Reference   01_005                          |----------------
132                                              |---------
                                                 |----
pillar           01_006                      ----|
132                                             -|
                                                 |
Roof Reference   01_007                          |
133                                              |
                                                 |
Roof Reference   01_008                       ---|
213                                             -|
                                                 |--------------
```

`Point id`	:Shows the point Ids defining the line or observation.
`Obs no.`	Observation number assigned by adjustment.
`Scale [mm]`	Graphical representation of residual. The residuals of Lat, Lon and Height are given (in that order) for each observation. In the case where Cartesian residuals have been selected, they will be displayed as dX, dY, dZ.

A table containing the numerical values of the residuals is displayed next. A shortened example is given.

```
Table with geodetic residuals:
-----------------------------

From point       To point         Obs no.   dLat      dLon     dHeight
-------------------------------------------------------------------------
Roof Reference   119              01_001   -0.0053    0.0081   -0.0038
Roof Reference   119              01_002    0.0012    0.0013    0.0055
pillar           119              01_003    0.0032   -0.0069   -0.0100
Roof Reference   130              01_004   -0.0000    0.0000    0.0000
Roof Reference   132              01_005    0.0184    0.0101    0.0044
pillar           132              01_006   -0.0053   -0.0016    0.0005
Roof Reference   133              01_007    0.0000    0.0000   -0.0000
Roof Reference   213              01_008   -0.0033   -0.0012    0.0158
```

`From point`	Start point of observation (reference)
`To point`	End point of observation (rover)
`Obs no.`	Observation number assigned by adjustment.
`dLat`	Latitude residual in metres
`dLon`	Longitude residual in metres
`dHeight`	Height residual in metres

The Geodetic variance/covariance matrices are then displayed. Matrices for single points are used to calculate the error ellipses. Other matrices (between points) may be used to calculate relative error ellipses. A shortened example is given.

```
Geodetic variance / covariance elements:
---------------------------------------

Point id        |Roof Reference               |pillar                       |
-----------------------------------------------------------------------------
Roof Reference  |  0.01497   0.00024  -0.00436| -0.01497  -0.00024   0.00436|
                |  0.00024   0.00896   0.00093| -0.00024  -0.00896  -0.00093|
                | -0.00436   0.00093   0.06718|  0.00436  -0.00093  -0.06718|
-----------------------------------------------------------------------------
pillar          | -0.01497  -0.00024   0.00436|  0.01497   0.00024  -0.00436|
                | -0.00024  -0.00896  -0.00093|  0.00024   0.00896   0.00093|
                |  0.00436  -0.00093  -0.06718| -0.00436   0.00093   0.06718|
-----------------------------------------------------------------------------

Point id        |119                          |130                          |
-----------------------------------------------------------------------------
119             |  0.18569  -0.00720  -0.10608|  0.00537  -0.00147  -0.00531|
                | -0.00720   0.08100  -0.04452| -0.00086   0.00394   0.00483|
                | -0.10608   0.04452   0.62771| -0.00392   0.00507   0.03215|
-----------------------------------------------------------------------------
130             |  0.00537  -0.00086  -0.00392|  0.49329   0.04361  -0.15987|
                | -0.00147   0.00394   0.00507|  0.04361   0.30758  -0.07032|
                | -0.00531   0.00483   0.03215| -0.15987  -0.07032   1.26852|
-----------------------------------------------------------------------------
```

The variance/covariance matrices between every point are displayed.
Reduced variance/covariance information is then displayed. This section contains the variance/covariance information for each point. This information is used to calculate the error ellipses.

The next section is the Outlier detection section. This section is rather important as it shows detected outliers. The information displayed here may be used to judge if the outlier detected must be discarded or if the error found is within limits acceptable to the operator. A shortened example is given.

```
Outlier detection:
-----------------

Critical tau value:  1.64         for tuned Alpha:  5.39 [%]

From point       To point         Obs no.  Stand. resid.    R[%]
```

```
-------------------------------------------------------------------
Roof Reference   119              01_001        0.00         78.53
                                                0.43         90.17
                                                0.41         68.92
Roof Reference   119              01_002        0.29         48.96
                                                0.57         31.28
                                                0.55         61.50
pillar           119              01_003        0.44         65.59
                                                0.90         70.71
                                                0.41         58.04
Roof Reference   130              01_004        0.00          0.00
                                                0.00          0.00
                                                0.00          0.00
Roof Reference   132              01_005        0.97         63.85
                                                1.16         64.35
                                                1.19         61.06
pillar           132              01_006        0.65         27.20
                                                0.27         28.06
                                                0.41         32.68
Roof Reference   133              01_007        0.00          0.00
                                                0.00          0.00
                                                0.00          0.00
Roof Reference   213              01_008        1.55         40.05
                                                0.25         54.63
                                                0.99         36.57
pillar           213              01_009        1.59         47.26
                                                0.71         28.55
                                                0.87         57.19
Roof Reference   214              01_010        0.02         53.60
                                                1.35         51.21
                                                1.20         68.38
Roof Reference   214              01_011        0.39         62.12
                                                1.67         78.34  ***
                                                0.24         51.84
pillar           214              01_012        1.37         74.00
                                                1.78         57.34  ***
                                                1.67         67.15  ***
```

`Critical tau value`	Tolerance for the standardised residual of an observation. Observations with a standardised residual above this value will be considered outliers. Calculated from the degree of freedom and the assigned Alpha and Beta values.

`for tuned Alpha`	The Alpha value is defined by the user in Settings... and may be described as the percentage risk of marking a good observation as an outlier. 5% is selected by default. Making the value lower (e.g. 1%) may result in bad observations being overlooked and not marked. In theory, the Alpha value is valid for an infinite number of observations, therefore it is tuned or amended slightly to account for the number of observations in the network.
`From point`	Start point of observation (reference)
`To point`	End point of observation (rover)
`Obs. no.`	Observation number assigned by adjustment.
`Stand. resid.`	Standardised residual of observation calculated by Residual/(Standard Deviation of Residual). The standardised residual is split into the three components of the coordinate (Lat, Lon Height or X,Y,Z)
`R[%}`	Redundancy factor of observation. Lines with only one observation have no redundancy (0%). Lines with more than one observation will have a higher redundancy (e.g. 70%). It is calculated from the variance/covariance information. Good Redundancy values are normally considered to be above 50%.

A more complete explanation of how to judge results displayed here is contained later in the manual.

The next section covers Internal Reliability. A shortened example is given.

```
Internal reliability (geodetic)
-------------------------------
                                              minimal detectable bias
From point        To point         Obs no.     Lat         Lon         Hgt
--------------------------------------------------------------------------
Roof Reference   119              01_001     0.0041      0.0042      0.0121
Roof Reference   119              01_002     0.0012      0.0018      0.0071
pillar           119              01_003     0.0018      0.0023      0.0096
Roof Reference   130              01_004    -------     -------     -------
Roof Reference   132              01_005     0.0004      0.0021      0.0087
pillar           132              01_006     0.0008      0.0018      0.0093
```

The internal reliability links the geometry of the network with the weighting and the residuals of the observations. It is a measure of ease with which gross errors may be detected by the outlier test.

`From point`	Start point of observation (reference)
`To point`	End point of observation (rover)
`Obs no.`	Observation number assigned by adjustment.
`minimal detectable bias`	Minimum value of error that can be detected by outlier test. This may be given in Lat, Lon and Height components for a geodetic logfile or as X, Y and Z components for a Cartesian logfile. These biases are a function of the Alpha value and of the power of the test (1-Beta) both of which may be set by the user in Settings... Note however that setting a very stringent 1-Beta test (E.g. 98%) may result in the test being too stringent and good results may be flagged as outliers.

The External Reliability section comes next.

```
External reliability (geodetic)
-------------------------------

Point                   dLat       dLon       dHgt
-----------------------------------------------------
Roof Reference         0.0000     0.0001     0.0003
pillar                 0.0000     0.0001     0.0003
119                    0.0003     0.0001     0.0007
130                    0.0001     0.0001     0.0002
132                    0.0001     0.0002     0.0005
133                    0.0001     0.0001     0.0002
213                    0.0001     0.0001     0.0002
214                    0.0002     0.0002     0.0004
215                    0.0006     0.0004     0.0010
306                    0.0001     0.0001     0.0002
309                    0.0001     0.0001     0.0003
313                    0.0000     0.0000     0.0002
316                    0.0000     0.0001     0.0005
p00                    0.0000     0.0001     0.0002
```

The External reliability shows the effect that undetected errors may have on the adjusted coordinates. It is an assessment of the undetected errors.

`Point`	Point Id
`dLat`	Maximum effect that an undetected error may have on the Latitude. When a Cartesian logfile has been selected this column will be for dX.
`dLon`	Maximum effect that an undetected error may have on the Longitude. When a Cartesian logfile has been selected this column will be for dY.
`dHgt`	Maximum effect that an undetected error may have on the Height. When a Cartesian logfile has been selected this column will be for dZ.

The adjusted geodetic coordinates are then listed. A shortened example is given.

```
Adjusted geodetic coordinates
-----------------------------

Roof Reference   Lat:  47 24 32.417187 N ± 0.00171 [m]
                 Lon:   9 37  2.726832 E ± 0.00132 [m]
                 Hgt:         452.3566   ± 0.00362 [m]

pillar           Lat:  47 22 58.312742 N ± 0.00171 [m]
                 Lon:   9 38 36.654879 E ± 0.00132 [m]
                 Hgt:         444.6654   ± 0.00362 [m]

119              Lat:  47 22 27.791335 N ± 0.00602 [m]
                 Lon:   9 36 12.151704 E ± 0.00398 [m]
                 Hgt:         438.3070   ± 0.01108 [m]
```

The coordinates for each point are given along with their respective standard deviations. Note that if a Cartesian logfile has been selected the coordinates will be in Cartesian format (X,Y,Z).

The next section deals with the computed confidence regions.

```
2-D and 1-D confidence regions
------------------------------

Confidence level:      68.00 %
1D expansion factor     0.9946
2D expansion factor     1.5096

Point            Semi major axis  Azimuth   Semi minor axis   Height
-----------------------------------------------------------------------
119                   0.0091       176.1         0.0060       0.0110
130                   0.0150        12.6         0.0115       0.0157
132                   0.0080       175.0         0.0070       0.0123
133                   0.0212        16.7         0.0191       0.0263
213                   0.0075         2.0         0.0046       0.0133
214                   0.0063       169.8         0.0052       0.0089
215                   0.0089       154.2         0.0068       0.0115
306                   0.0076         8.1         0.0052       0.0084
309                   0.0119        22.7         0.0079       0.0191
313                   0.0116         3.9         0.0076       0.0118
316                   0.0088        16.4         0.0068       0.0115
Roof Reference        0.0026         2.3         0.0020       0.0036
p00                   0.0052       166.1         0.0043       0.0079
pillar                0.0026         2.3         0.0020       0.0036
```

The confidence regions are statements of the precision of a point. They show the position and height error. The 2D confidence region is described by an error ellipse which shows the position uncertainty of a point in all directions. The 1D confidence region shows the uncertainty of the height of a point.

`Confidence level:`	The level of confidence that the position and height lies within the values computed. This is normally 1 sigma (68%) or 2 sigma (95%).
`1D expansion factor`	Expansion factor for the height computed from the confidence level.
`2D expansion factor`	Expansion factor for the position computed from the confidence level.
`Point`	Point Id
`Semi major axis`	Size in metres of semi major axis of error ellipse.
`Azimuth`	Direction in degrees with respect to north of the semi major axis.
`Semi minor axis`	Size in metres of semi minor axis of error ellipse.
`Height`	Height bar in metres

8.5.1.2 What to look for in the Logfile

The first part of the logfile that requires examination is the residuals part. Examine the graphical results.

```
Geodetic Residuals
------------------

Point id        Obs no.
(from/to)                                                       Scale [mm]
                        -27     -18     -9       0       9      18      27
                         +-------+-------+-------+-------+-------+-------+-------+
Roof Reference   01_001                      ----|
119                                              |-------
                                              ---|
Roof Reference   01_002                          |-
119                                              |-
                                                 |-----
pillar           01_003                          |--
119                                        ------|
                                        ---------|
Roof Reference   01_004                          |
130                                              |
                                                 |
Roof Reference   01_005                          |----------------
132                                              |---------
                                                 |----
pillar           01_006                      ----|
132                                             -|
                                                 |
Roof Reference   01_007                          |
133                                              |
                                                 |
Roof Reference   01_008                       ---|
213                                             -|
                                                 |--------------
```

Look for large residuals. This may indicate a problem. However, a large residual does not necessarily mean that the observation is bad. The length of the line should also be taken into account. This is demonstrated in the case where a long baseline has larger residuals than a short baseline, yet the long baseline has a higher accuracy.

The length of the baseline is taken into account when a Standardised Residual is computed for an observation. The Standardised Residual is used in the Tau test and therefore, this test gives a better indication if errors exist or not. The Tau test is performed during Outlier detection.

```
Outlier detection:
-----------------

Critical tau value:  1.64         for tuned Alpha:  5.39 [%]

From point       To point         Obs no.  Stand. resid.    R[%]
-------------------------------------------------------------------
Roof Reference   119              01_001        0.00        78.53
                                                0.43        90.17
                                                0.41        68.92
Roof Reference   119              01_002        0.29        48.96
                                                0.57        31.28
                                                0.55        61.50
pillar           119              01_003        0.44        65.59
                                                0.90        70.71
                                                0.41        58.04
Roof Reference   130              01_004        0.00         0.00
                                                0.00         0.00
                                                0.00         0.00
Roof Reference   132              01_005        0.97        63.85
                                                1.16        64.35
                                                1.19        61.06
pillar           132              01_006        0.65        27.20
                                                0.27        28.06
                                                0.41        32.68
Roof Reference   133              01_007        0.00         0.00
                                                0.00         0.00
                                                0.00         0.00
Roof Reference   213              01_008        1.55        40.05
                                                0.25        54.63
                                                0.99        36.57
pillar           213              01_009        1.59        47.26
                                                0.71        28.55
                                                0.87        57.19
Roof Reference   214              01_010        0.02        53.60
                                                1.35        51.21
                                                1.20        68.38
Roof Reference   214              01_011        0.39        62.12
                                                1.67        78.34  ***
                                                0.24        51.84
pillar           214              01_012        1.37        74.00
                                                1.78        57.34  ***
                                                1.67        67.15  ***
```

The Tau test works by firstly determining a Critical Tau value. This value is based upon the number of observations, the number of unknowns (coordinates) and the confidence level (Alpha, input by the user).

The number of observations is found by the number of lines in the network multiplied by three. Each time a line is measured using

GPS, a vector is produced comprised of three elements (ΔX, ΔY and ΔZ).

The number of unknowns can be considered to be the number of unknown points, multiplied by 3 (i.e. the XYZ components).

The confidence level (Alpha) is input by the user in Settings.... The Alpha value is the percentage risk of marking a good observation as an outlier. The default value for this is 5% as it is considered that this offers a good compromise. Note that lowering the value to 1% or so may decrease the risk of marking a good observation as an outlier but may also increase the risk of a bad observation not being marked as an outlier.

The list of observations, their computed standardised residuals and redundancy is given. If the standardised residual of an observations is greater than the critical tau value, it will be marked as an outlier by three stars.

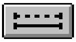
The operator must now decide how to handle the outliers. Firstly find the largest outlier (the observation with the largest Standardised Residual). Compare this with the Critical Tau value. Is there a great difference? If the Standardised Residual is close to the Tau value it may be that the result will be acceptable even though it is marked as an outlier.

Additionally, if only one component of the observation is marked as an outlier, it may be that the result is acceptable.

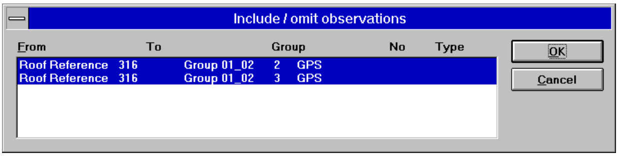
If two or all three components of the observation are marked as outliers, and these values are significantly larger than the Critical Tau value then there is a high probability that this observation may be treated as an outlier. It should be removed from the network and the network recomputed.

8.5.1.3 Omitting observations

If an outlier has been found and it is felt that it would be prudent to omit the observation from the free adjustment, proceed as follows.



With the network displayed, click on the include/omit observation button or select Include/Omit observations from the Edit menu.
Select the observations you wish to omit by clicking on them with the mouse. If you select a line where several observations have been taken, the following dialogue box will appear where you can select the observation(s) you wish to omit.



Select the observation you wish to omit and click on OK.

The observation will be shown in grey rather than red. Note that if several observations exist on the same line, the omitted observation may not be visible.

When you are satisfied that you have located the outliers that have large effects on the overall network and omitted the observations, you may proceed with the constrained adjustment.

8.5.2 Types of Constrained Adjustment

The constrained adjustment is used when you wish to tie in new measurements with an existing network. To fully constrain an adjustment you must keep two or more points fixed. This means that you must have at least two points in your network that are also contained in the network you are tying in to. Note you may constrain position or height, see below.

The other option is a minimally constrained adjustment. In this type of adjustment, one point is constrained or held fixed in position and height and the adjustment takes place around it. The results will tend to swing around the fixed point.

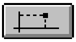
Generally, a minimally constrained adjustment is where one point is fixed in position and height. However the position and height do not necessarily have to be on the same point. Hence if you have a point for which the height is no good, you may constrain the position only and constrain the height on a different point. Constraining more than three components, E.g. one position and two heights would make the adjustment a constrained adjustment, not a minimally constrained adjustment.

A further option for both minimally constrained and constrained adjustments is the relative fixing of points. If you have standard deviation information for the points you wish to fix, you may classify the point as a Relative Fixed point and enter the Standard Deviation. When the adjustment computation is carried out, the Relative fixed points may be also shifted slightly depending on the weighting information given.

Note that a minimally constrained adjustment is very similar to a free adjustment and is not a mandatory step to perform in the adjustment process. To fix new measurements rigorously into an existing network, a constrained adjustment must be performed.

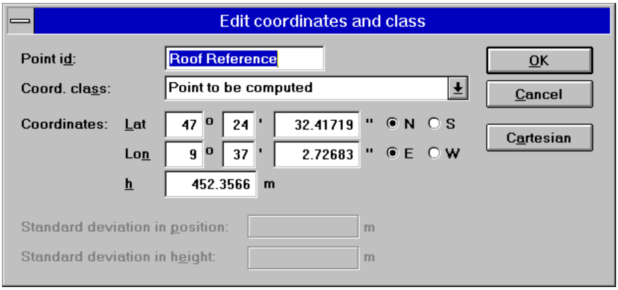
8.5.2.1 Minimally Constrained Adjustment

To constrain the adjustment minimally, proceed as follows:



With the network displayed, click on the edit coordinates and class button or select Coordinate and class from the Edit menu.

Double click on the point that you wish to fix. The following dialogue box will appear:



Change the Coord. class as required. Refer to the previous section for an explanation of the options available.

Then modify the coordinates to match those from your existing network. If you are entering a Relatively fixed point, enter the standard deviations as well.

When you have fixed the required number of points (for minimal constraint one position and one height) press the compute button or select Compute from the menu bar.

The computation will run as with the Free Adjustment with any outliers being detected. Study the Logfile and handle any outliers as described under free adjustment.

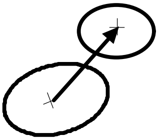
8.5.2.2 Constrained Adjustment

When performing a constrained adjustment, proceed as with a Minimally Constrained Adjustment. Remember that for an adjustment to be considered as constrained, you should fix more than one position and one height.

Relative fixed positions may also be used in a Constrained Adjustment.

SECTION 4 - Guidelines to Datum/Map

9 Guidelines to Datum/Map



Datum/Map is a valuable option for SKI. It enables you to transform coordinates between coordinate systems. You can also use Datum/Map to determine the parameters necessary to carry out such transformations.

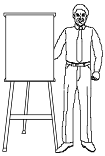
9.1 Introduction

Using Datum/Map you may carry out the following operations:

- Import and export coordinates, reference ellipsoids, map projections, geoidal models and transformation sets.
- Determine transformation parameters and define transformation sets.
- Perform coordinate transformations from one system to another.

9.2 Background

9.2.1 The need for a transformation



When measuring with GPS there is usually a need for a transformation because GPS measures coordinates on a different system to that used in any one particular country. Therefore the results obtained from GPS need to be transformed into the local coordinate system.

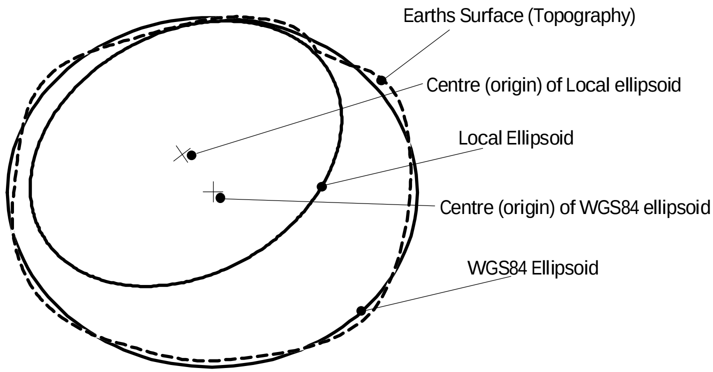
9.2.2 Local coordinate systems

When the term "local coordinate system" is used it usually means a coordinate system used by a particular country or part of a particular country. Such coordinate systems usually give coordinates in terms of Eastings (x axis), Northings (z axis) and heights above sea level (orthometric heights) with reference to a map projection.

Local or Grid coordinate systems are normally based on a plane grid. However, the earth may be more accurately described as an ellipsoid and therefore, the curvature of the ellipsoid must somehow be taken into account. For this reason, local grid coordinate systems always have some defining parameters that allows them to be directly related to this imaginary ellipsoidal surface that approximates to the shape of the earth. These defining parameters are referred to in SKI as Map Projection Parameters and the imaginary ellipsoidal surface as the Local Ellipsoid. Note that there are different methods for defining the Map Projection parameters. The most common are supported in Datum/Map.

Local Ellipsoids are so called because they normally only apply to a certain specific area of the earth's surface. This is due to the fact that most were defined many years ago before the advent of modern space measuring techniques and whilst adequately approximating to the country or continent in which they were defined, they do not adequately approximate to the earth's shape as a whole. Thus, the Local Ellipsoid used for a particular country or group of countries varies with the location of the country/ies on the earth's surface.

Ellipsoids that better approximate the earth's surface have only been defined in recent years since the advent of modern space techniques. GPS measures with reference to an ellipsoid called WGS84 or World Geodetic System 1984.

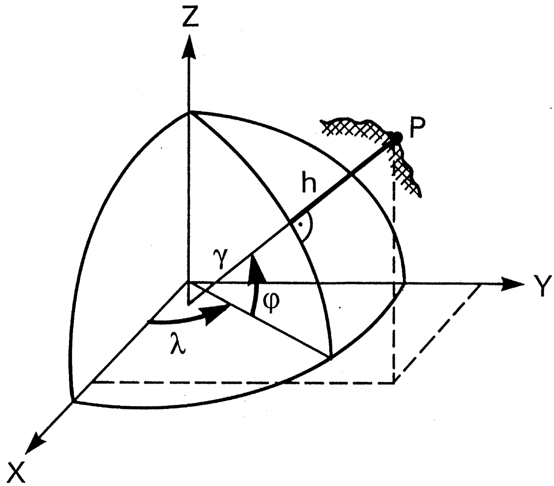


Relationship of a local ellipsoid, the WGS84 ellipsoid and the earth's topography
(exaggerated for reasons of clarity)

There is therefore a requirement for the results produced by SKI to be transformed from the WGS84 ellipsoidal system to the local ellipsoidal system.

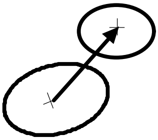
Points defined on an ellipsoidal system (local or WGS84) are not given coordinates in the same way as the same points defined on a Local Grid system. There are two methods for defining points on an ellipsoidal system. The first and most commonly used is by Latitude, Longitude and Height. The second (and more useful in terms of transforming coordinates), is by X, Y and Z coordinates from the origin of the ellipsoid. This is known as a Cartesian system and is the system used during datum transformation.

The point P in the diagram below is defined by using both of these methods.



λ = Ellipsoidal Longitude
φ = Ellipsoidal Latitude
h = Ellipsoidal Height
γ = Radius of curvature in prime vertical

9.2.3 Methods of Datum Transformation



In the past before the advent of satellite surveying techniques most surveyors did not have to concern themselves with such things as ellipsoids and map projection parameters etc. This type of work was left to Geodetic Engineers. However
since the advent of satellite surveying and it's increasing use by surveyors it has become necessary for them to understand some of the basic concepts behind geodesy.

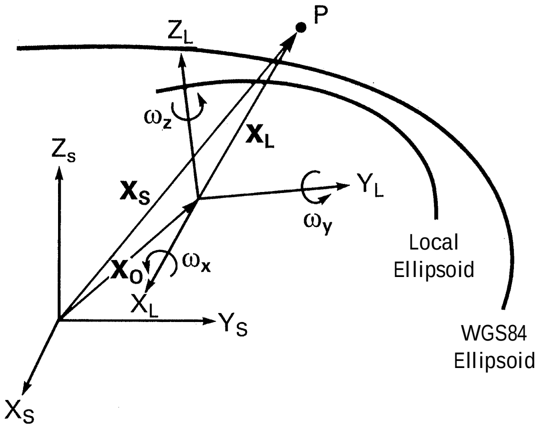
When datum transformations were first considered for the purposes of transforming coordinates measured on the WGS system to a local system the 3D Helmert transformation model was used. This is the most rigorous and accurate method for transforming coordinates from one ellipsoidal system to another but for the normal land surveyor using GPS has some practical drawbacks.

The 3D Helmert transformation approach is the Classical approach contained in SKI.

It works by taking the origins and axes of the two ellipsoidal coordinate systems (when using GPS this is usually WGS84 and a local ellipsoid) and calculating the following:

1. The shifts required in x, y and z to move the origin of the WGS84 ellipsoid to that of the local ellipsoid.
2. If the local ellipsoid has a different orientation to the WGS84 ellipsoid, the rotations about x, y and z to orient the origin correctly.
3. If the ellipsoids are different sizes, a scale factor between the two ellipsoids.

The diagram over shows graphically how this transformation approach works.



P = defined point
X_S = Position in WGS84 system
X_L = Position in local system
X_O = Translation Parameters (Shifts in X, Y and Z)
ϖx, ϖy, ϖz = Rotation angles about the three axes

As mentioned above, this approach is mathematically correct and will maintain the accuracy of any GPS measurements but for practical purposes has several restrictions or disadvantages. These are:

1. In order for the transformation to work properly, at least three homogenous points must be known <u>accurately</u> in the local coordinate system. It is preferable to know four or more local points for purposes of error reduction. If the coordinates of the local points are not accurate or homogenous the transformation parameters will not function correctly and errors will result.

2. The largest errors in most local coordinates are contained in the height. Because of the way in which the Cartesian coordinate system of the local ellipsoid works, any error in the local height component is translated into an error in the X, Y and Z coordinates of the Cartesian system. Hence when other new coordinates are subsequently transformed from WGS84 to the local ellipsoid and then mapped onto the local projection, errors in position and height will be present.

3. In order to obtain accurate ellipsoidal heights the geoid separation at the measured points must be known. This may be determined form a geoidal model. Many countries do not have access to an accurate local geoidal model. See also the next section on heighting.

For these reasons, there are several transformation approaches in SKI software.

A totally different transformation approach is the Interpolation approach. This approach does not rely on knowledge of the local map projection parameters or local ellipsoid. Additionally, any inaccuracy in the local coordinates is dealt with by "stretching" or "squeezing" the WGS84 (GPS) coordinates to fit into the local system. Therefore any points measured with GPS will be made to fit homogeneously into the existing local map projection.

Thus, this approach can be used successfully in situations where the local coordinates may not be totally homogenous.

Additionally, fewer problems will be encountered with height as a local height model is built up over the transformation area.

The main disadvantage with this method is that it is restricted in the area over which it can be applied. Typically, the transformation area should not exceed 10-15km square.

Other transformation approaches contained within SKI are the Stepwise approach and the Onestep approach.

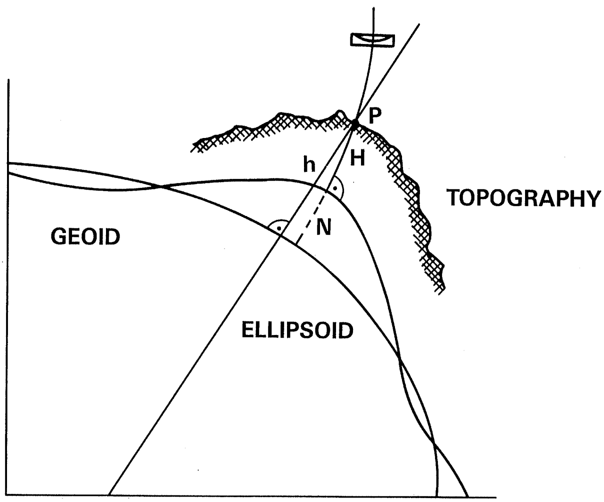
The Stepwise approach combines a 2D Helmert transformation for position with a height interpolation. Therefore, some of the disadvantages of the 3D Helmert approach are overcome. i.e. height is independent of position and as in the Interpolation approach, a local height model is constructed from the local height information supplied.

The Onestep approach is useful when only small amounts of local coordinate information are available. As described later, it is possible to calculate transformation parameters using this method from only one or two sets of local coordinates.

9.2.4 Heighting and the Geoid

Unfortunately there may be a further complication when calculating transformation parameters. Such complications will usually only be noticed in very mountainous areas where there are sudden large undulations in the geoid.

The heights that are given with position coordinates of known control points are usually orthometric heights (heights with reference to mean sea level or the geoid). In order to obtain a "true" ellipsoidal height so that the Cartesian coordinates of the point on the local ellipsoid can be determined, the separation between the geoid and local ellipsoid should be known. This is explained further in the diagram below.



h = Ellipsoidal height
H = Height above Geoid (orthometric height)
N = Geoid separation

Ideally, the geoid separation will be available on the points that are used for the transformation. In 99% of cases this is not so. It may also be that a geoidal model exists for the country or local area in which you are working. If this is the case, the geoid separation may be determined from the geoidal model. (SKI will perform this if a program for the geoidal model is available).

Normally, however this may not be the case. As stated above, if the area is not mountainous then it is very unlikely that there will be any sudden large changes in the geoid. Such large changes in the geoid tend to occur where there are sudden large changes in the earth's surface.

Shifts and tilts between the Geoid and Ellipsoid are compensated for by 3-D transformation parameters. Note also that using the Stepwise Transformation approach can especially negate the problem of lack of Geoidal Height information.

9.3 Overview

In general, when using Datum/Map the procedure is as follows:

1. Import GPS coordinates from SKI. These will be coordinates based on the WGS84 ellipsoid and may come straight from Data Processing (unadjusted) or from the Adjustment option after an adjustment has been performed.

2. Import or define points in the local coordinate system. Note that you should normally have a minumum of 3 points in common with the GPS points.

3. Determine the transformation parameters.

4. Transform the remaining GPS coordinates into the local system.

9.4 Datum Transformation approaches

There are several methods in SKI by which datum transformation parameters can be determined. These are:
Classical
Interpolation
Stepwise
One Step
Each of these transformation approaches have advantages and disadvantages and should be selected according to the local conditions.

9.4.1 The Classical approach

The Classical transformation approach in Datum/Map creates transformation parameters using a rigorous 3D or 2D Helmert method.
Basically, the method works by taking the Cartesian coordinates of the GPS measured points (WGS84 ellipsoid) and comparing them with the Cartesian coordinates of the local coordinates. From this, shifts and rotations and a scale factor are calculated in order to transform from one ellipsoid to another.

For this method, we recommend that you have at least three points for which the coordinates are known in the local grid system and in WGS84. It is possible to compute transformation parameters using only three common points but using four allows for residuals to be calculated. In addition you need to know the type of map projection on which the local coordinates are based and it's parameters as well as the local ellipsoid used.

The advantages of this method of calculating transformation parameters are that it maintains the accuracy of the GPS measurements and may be used over virtually any area as long as the local coordinates (including height) are accurate.

The main disadvantage is that the local ellipsoid and map projections must be known and if the local coordinates are not accurate within themselves, any new points measured using GPS may not fit into this existing local system once transformed.

9.4.2 The Interpolation approach

The Interpolation approach creates transformation parameters based on an affine transformation model that uses a collocation approach to estimate the systematic part of the noise.

Basically what this means is that the WGS84 coordinates measured by the GPS are squeezed or stretched to fit the local grid. The local grid is constructed using the entered grid coordinates.

Position and height are treated separately and as such are independent of each other. This means that the measured position points do not necessarily have to be the same points for which height is known and that errors in local height measurement will not be propagated into the position transformation component.

The Interpolation approach has certain advantages over a traditional 3D Helmert (Classical) approach in that parameters can be calculated without knowledge of the map projection or local ellipsoid. Additionally, heights and position are transformed independently of each other. This means that: the local coordinates do not have to contain the height information. The height information may be obtained from different points.

The main disadvantage of the interpolation approach is that it is restricted in the area over which it can be applied. This is mainly due to the fact that there is no provision for scale factor in the projection. In practical terms, the area over which this transformation approach can be applied is about 10-15km square.

The Interpolation approach will tend to distort the GPS measurements to fit the existing local grid measurements. This may be an advantage or disadvantage as the GPS coordinates are generally found to be better than the existing grid coordinates. That is to say that they are more homogenous.

This means that the accuracy of the GPS coordinates may be slightly compromised when using this method. This may be no bad thing if you want new transformed GPS points to tie in with your existing local network.

The basic algorithm for this approach was developed, on contract, by Dr. B. Wirth of the Geodesy Division of the Institute of Geodesy and Photogrammetry of the Swiss Federal Technical Institute, Zürich (ETH-Z).

9.4.3 The Stepwise approach

The Stepwise transformation approach is effectively a combination of the Classical method and the Interpolation method. The position and height transformations are split into two separate components. A Classical transformation approach is used for the position transformation and an Interpolation method used for the height.

For this method, we recommend that you have at least four points for which the coordinates are known in the local grid system and in WGS84. It is possible to compute transformation parameters using only three common points but using four allows for residuals to be calculated. In addition you need to know the type of map projection on which the local coordinates are based and it's parameters, as well as the local ellipsoid used.

Because this approach splits the transformation into two separate components position and height are independent of each other as with the Interpolation method. This means that the points used for determining the position and height transformation do not necessarily have to be the same points.

As the position transformation is determined using the Classical approach, the transformation area may be larger than with the Interpolation approach. The limiting factor being the accuracy of the height transformation. (See next section).

Basically, the method works thus:
1. The centre of gravity of the common points is computed.
2. The shifts between WGS84 and the local ellipsoid are computed.
3. The map projection is applied to the WGS84 points.
4. The 2-D helmert transformation parameters are determined.
5. The height interpolation is determined.

In flat or relatively flat areas, where good heights are available in the local system, the approach will have no problem in constructing a good height transformation for relatively large areas. The more height points included, the better the height transformation will be.

In areas where it is suspected that the geoid undulation is extreme, the area over which the transformation is carried out should be reduced if accurate heighting is required. Note that position will not be affected by extreme geoid undulations.

The advantages of this transformation approach are:
1. The height and position transformations are separate. This means that :
a. Errors in local heights do not affect the position transformation
b. The points used for determining the position and height transformation do not necessarily have to be the same points.

2. The height transformation method will provide accurate height transformations without any knowledge of geoid separations as long as the geoid/ellipsoid separation is reasonably constant and does not contain sudden changes. The more height points included, the better the model.

The disadvantages of this transformation approach are:
1. Knowledge of the local map projection and local ellipsoid are required.

9.4.4 The One Step approach

This transformation approach works by again treating the height and position transformations separately. For the position transformation, the WGS84 coordinates are projected onto a temporary Transverse Mercator projection and then the shifts, rotation and scale from the temporary projection to the "real" projection are calculated.

The Height transformation is a single dimension height approximation.

This transformation approach is supported in the Controller and therefore is also supported here. It is not likely that this transformation approach would be chosen by a SKI user in preference to (say) the interpolation approach to which this approach is similar.

Because of the way in which the position transformation approach works it is possible to define a transformation without any knowledge of the local map projection or local ellipsoid.

As with the Interpolation and Stepwise approaches, the height and position transformations are separate and therefore errors in height do not propagate into errors in position. Additionally, if knowledge of local heights is not good or non-existent you can still create a transformation for position only. Also, the height points and position points do not have to be the same points.

Because of the way in which the transformation works it is possible to compute transformation parameters with just one point in the local and WGS84 system.

The combinations of the number of points in position and the position transformation parameters that can be calculated from them are as follows:

No. of position points	Transformation Parameters Computed
1	2D Helmert with shift in X and Y only
2	2D Helmert with shift in X and Y, Rotation about X and Y and Scale
More than 2	2D Helmert with shift in X and Y, Rotation about X and Y, Scale and Residuals

The number of points with height included in the transformation directly affects the type of height transformation produced.

No. of height points	Height transformation based on
0	No height transformation
1	Constant height transformation
2	Average constant between the two height points.
3	Plane through the three height points
more than 3	Average plane

The advantages of this method are that transformation parameters may be computed using very little information. No knowledge is needed of the local ellipsoid and map projection and parameters may be computed with the minimum of points. Care should be taken however when computing parameters using just one or two local points as the parameters calculated will only be valid in the vicinity of the points used for the transformation.

Disadvantages of this approach are the same as for the Interpolation approach in that the area of the transformation is restricted to about 10km square (Using 4 common points).

9.5 Which approach to use

This question is almost impossible to answer since the approach used will depend totally on local conditions and information.

If you wish to keep the GPS measurements totally homogenous and the information about the local map projection is available, the Classical approach would be the most suitable.

If you are unsure of the local height information but the position information is accurate and you wish to keep the GPS measurements homogenous in position, then the Stepwise approach may be the most suitable.

For cases where there is no information regarding the ellipsoid and/or map projection and/or you wish to force the GPS measurements to tie in with local existing control then the One Step or Interpolation approach may be the most suitable.

9.6 Operation within SKI

The operations that need to be carried out are:

1. Import the coordinate sets (local and WGS84 measured by GPS) into Datum/Map
2. In Transformation Parameters match the common points of each coordinate set.
3. Compute the transformation
4. Transform any GPS coordinates contained within the transformation area.

Most users will not wish to define a local geoidal model. However, information on specifying a local geoidal model program for use is contained in the SKI help files.

9.6.1 Importing the Coordinate sets

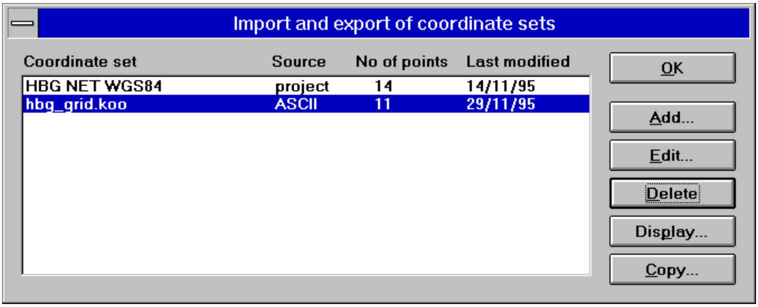
In order that Transformation Parameters may be computed, you require two sets of coordinates in the Datum/Map component.

In most cases, one of these coordinate sets will be the WGS84 coordinates taken by the GPS equipment and computed by SKI. The other coordinate set will be the coordinates of the measured points in the local coordinate system.

9.6.1.1 Importing the GPS Coordinates

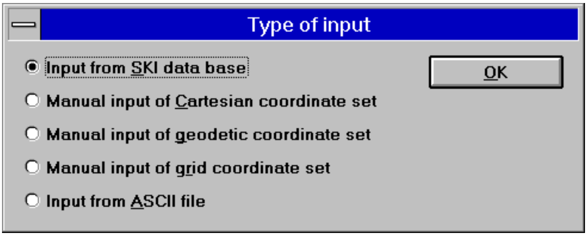
To get the WGS84 coordinates into Datum/Map from a SKI project, perform the following operation:

From the SKI main menu select Datum/Map, Import/Export, Coordinate Sets. The following dialogue box will appear:



Any Coordinate Sets already contained in Datum/Map will be listed. To add new Coordinate Sets press **Add**.

Upon pressing **Add** the a dialogue box will appear that will allow you to enter or add coordinate sets from one of several possible sources. To add a coordinate set from a SKI project press **Input Type**. The following list will appear



Ensure that "Input from SKI data base" is selected and press **OK**.

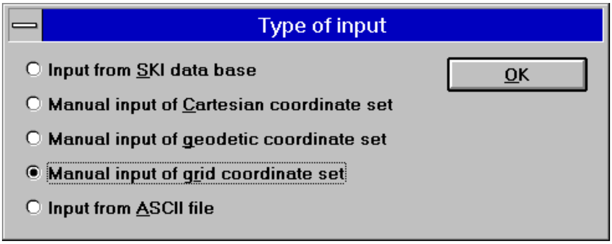
A dialogue box containing all the current SKI projects will appear. Select the project which contains the coordinates you wish to use to calculate the transformation parameters, enter a name for the coordinate set and press **OK**. Note that it is advisable to use a name that you will recognise at a later stage and that you know where the coordinates have come from. E.g. "WGS84 Test coords".

Note that if you wish to calculate Transformation Parameters using the Classical or Stepwise methods later on the coordinates must be in Cartesian form. To change from Geodetic to Cartesian press **Edit** and then **Cartesian**. Press **OK** to continue.

9.6.1.2 Importing the Local Grid Coordinates

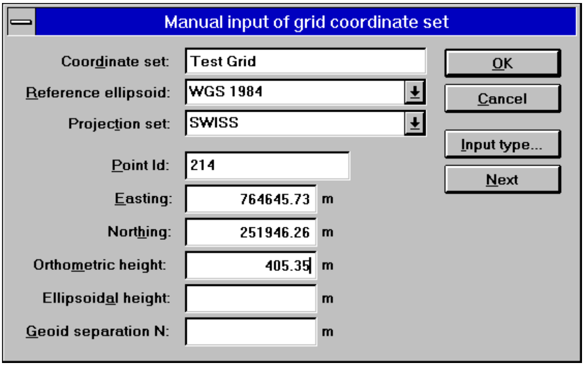
There are two methods of entering the local grid coordinates. You may manually type in the information, or you may specify an ASCII file to be imported. The required file format for ASCII input is contained in the first section of this manual.

To enter a local grid coordinate set manually
select Datum/Map from the SKI main menu. Then select Import/Export and Coordinate Sets. Press **Add** and then **Input Type**. The following dialogue box will appear:



Select "Manual input of grid coordinate set" and press **OK**

The following dialogue box will appear



Enter a name for the coordinate set. Note that it is advisable to use a name that you will recognise at a later stage and that you know where the coordinates have come from. E.g. "Grid Test coords".

If you wish to perform either a Classical or Stepwise type transformation, you must define the Reference ellipsoid and Projection set. Most Reference ellipsoids used throughout the world are contained in SKI. If you have not previously defined a Projection set then you will need to do this before entering the coordinate set. Details are contained in the next section.

Enter the point Id of the first point, it's Easting (y), Northing (x), and height values. Note that most heights given out by mapping agencies are orthometric heights. If the ellipsoidal height or geoid separation information is available, enter these values also. This will allow you to create transformation parameters that can be used to determine ellipsoidal height of any point within the transformation area.

When all the information for a particular point is entered press **Next**.

You may now enter information for the next point. Note that the ellipsoid and projection parameters remain the same. Highlight the point Id and enter the next one. Use the Tab key to move to the next input field. The previously entered value will be automatically highlighted. You may type in a new value.

Repeat the process until all the coordinate information has been entered. Then press **OK**.

To import local coordinates from an ASCII file, navigate to the Type of Input dialogue box as shown previously. Select "Input from ASCII file" and press **OK**.

Select the drive and path where the ASCII file is stored. Click on the file. Enter a name for the coordinate set. Note that it is advisable to use a name that you will recognise at a later stage and that you know where the coordinates have come from. E.g. "Grid Test coords".

Press **OK**.

Note that in order to compute Classical or Stepwise Transformation Parameters the coordinates have to be in Cartesian form. Additionally the Map Projection and Local Ellipsoid has to be defined as explained previously. To change the coordinates into Cartesian form press **Edit** and then **Cartesian**. Press **OK** to continue.

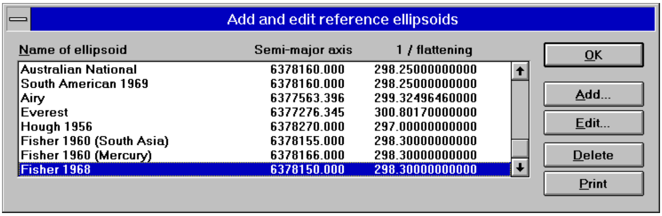
You should now have two sets of coordinates in the Datum/Map database.

9.6.2 Defining a Local Ellipsoid

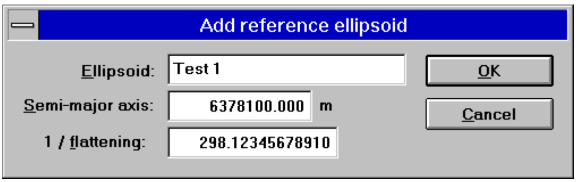
In the cases where Classical or Stepwise transformation parameters are going to be computed, the ellipsoid parameters must be contained in the Dtaum/Map database. Most of the ellipsoids in use around the world are already defined and contained in this database.

To define a new ellipsoid:

Select Datum/Map from the SKI Main Menu. Select Import/Export and Reference ellipsoids.... The following window will appear:



Click on Add. The following window will appear where you may define the parameters for the new reference ellipsoid.

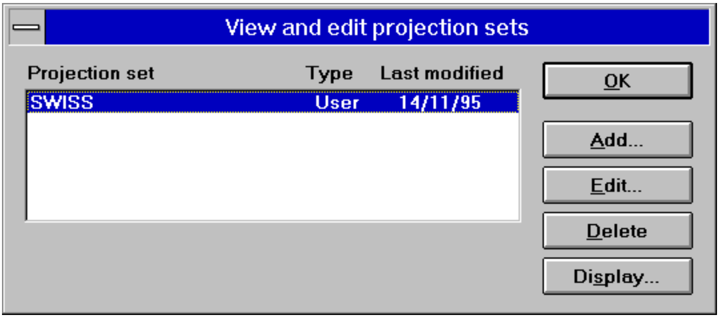


Enter the parameters and click on OK.

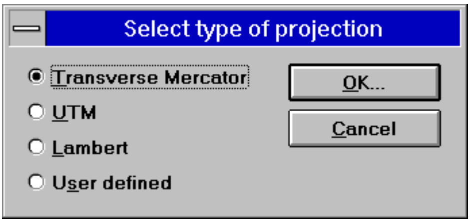
9.6.3 Defining a Map Projection

A map projection may be defined in SKI by performing the following operation:

Select the Datum/Map component from the SKI main menu. Select Import/Export and Map Projection Sets. The following dialogue box will appear:



Any projection sets already defined are displayed in the list. To enter a new projection set press **Add**. The following dialogue box will be displayed:



Select the type of projection that you wish to define and press **OK**. Then enter the relevant parameters for the map projection. Note that in the case of a User Defined projection, you must define the path where the exe program can be found. Map projection parameters can usually be obtained from local or national mapping agencies. When the parameters have been entered press **OK**. Certain special projections that are cannot be defined using Transverse Mercator, UTM or Lambert have been hardwired into SKI. These are:

Swiss projection
New Zealand Grid
Malayan RSO Grid

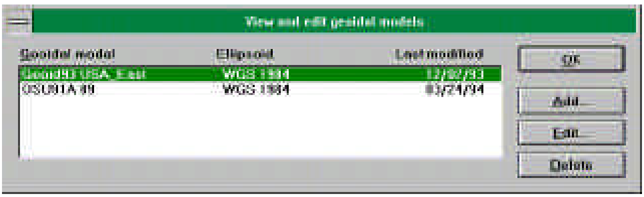
These projections will be available when it is required that a map projection is to be defined but will not be seen in the View and edit map projections dialogue box due to the fact that they may not be edited.

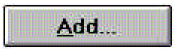
9.6.4 Defining a Local Geoidal model

A Local Geoidal model program, written by a third party may be used by SKI. This program should be an executable file (i.e. a .exe file). SKI merely has to know where the program is located.

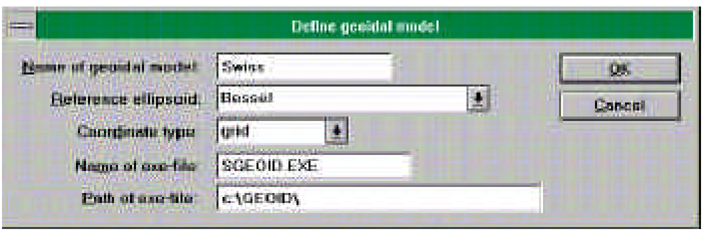
A geoidal model program may be defined by performing the following operation:

From the SKI Main Menu, select the Datum/Map option. Select Import/Export and then Geoidal Models. The following dialogue box will appear:





To define a new Geoidal Model program press **Add**. The following dialogue box will appear:



Enter the various parameters required and press **OK**.

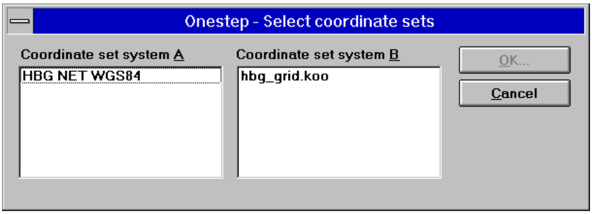
9.6.5 Calculating the Transformation Parameters

The Transformation Parameters are calculated by using one of the four methods contained in SKI. Decide which method is most suited to the data that you have. Refer to previous sections in this guide.

Select Datum/Map from the SKI main menu and then Transformation Parameters. Select the method you wish to use.

9.6.5.1 Choosing the Coordinate Sets

With all methods, you will be asked to select which coordinate sets to match. The following dialogue box will appear:



You need to select which coordinate sets to match. System A is the system you are coming from, System B the system you are going to. Hence, in most cases System A will be the WGS84 coordinates measured by GPS, System B will be the local grid coordinates.

When the Interpolate approach is used there is an extra section at the bottom of the dialogue box entitled "Distortion of System A". This allows you to decide how much the geometry of System A (in most cases, the GPS coordinates), will be distorted towards the geometry of System B (in most cases, the local grid coordinates).

The four different settings can be summarised as follows:

Distortion of System A	Effect on System A
High	Geometry maximally distorted toward System B
Medium	Between High and Low
Low	Geometry preserved as much as possible
None	Geometry completely preserved

Which setting to use will depend upon what your application is and how reliable your local grid coordinates are.

Guidelines are as follows:

If System A has to "match" (i.e. residuals are minimised) System B then choose High as the setting. The homogenity of System A will be distorted. If System A is WGS84 coordinates measured with GPS it will almost certainly be more homogenous than any existing local control. Setting Low or None will not distort System A to fit System B. The homogenity of System A will be preserved. Use ‘High’ when you want any further points measured with GPS to tie in with existing terrestrial measurements.

If you have very accurate and reliable positions in the local system but unreliable heights, choose Low for position and High for the height.

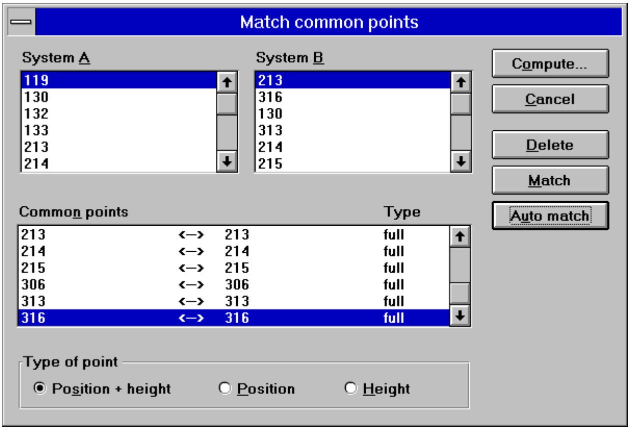
If you wish to preserve the homogenity of System A, (the GPS measurements), choose Low for both position and height.

Note that the above are guidelines only and may not apply in every case.

Press **OK** to continue.

9.6.5.2 Matching the Coordinates

When you have selected which Coordinate Sets you wish to match, a dialogue box will appear asking you to select which points are the common points in each system. The dialogue box is displayed as below:

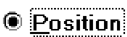


You may now proceed to match the common points in the two systems by either;

1. clicking on each pair of points with the mouse and pressing **Match** or;

2. If the common points have the same Id's pressing **Auto Match**.

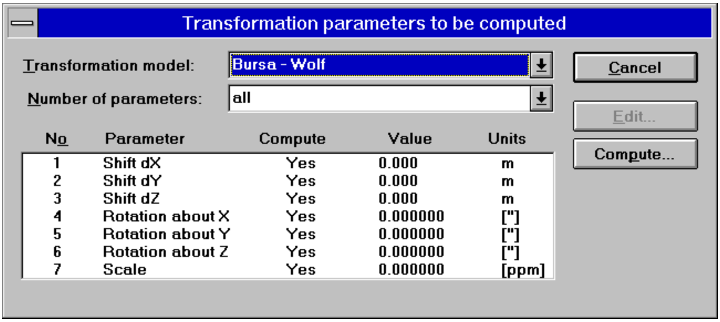
Additionally, with the Interpolation, Stepwise and Onestep approaches you may match points which in the local system (System B), you have only good position information (height is unreliable), or points where only height is available.



To match points in position only select Position at the bottom of the screen and match as above.

To match points in height only select Height and match as above.

Note that when classical type transformation parameters are being computed the following additional dialogue box will appear whereby you may choose the parameters to be computed and the Transformation Model to be used.



There are two transformation models contained in SKI, the Bursa-Wolf model and the Molodensky-Badekas model. For practical purposes there will be no difference in the results obtained using either of these two models. However, for reasons of completeness the two different models are defined below.

The Bursa–Wolf Model

The rotation origin is always identical to the origin of the system A. The translation vector (shifts) goes **from** the origin of system A **to** the origin of system B. Because the common points are far away from the rotation centre, a high degree of correlation exists between the rotation and shift parameters. This can easily be seen in the **high r.m.s. values of the shift parameters** when applying this model to a small area.

However, due to the reason of having always the same rotation origin this model is normally used to publish official transformation parameters between WGS84 datum and local datum.

The Molodensky–Badekas Model

The rotation origin lies in the centre of the common points of system A (i.e., at the mean of the X, Y, Z coordinates). Therefore this origin varies according to the common points that are used. Therefore, this model is not normally used when publishing transformation parameters. The shift parameters are the translation vector components **from** the centre of common points of system A **to** the centre of common points of system B. The Molodensky–Badekas model displays far less correlation between rotation and translation parameters than does the Bursa – Wolf model. This can be seen in the smaller r.m.s. of the shift parameters when applying this model to the same small area that was mentioned above.

The rotation parameters, residuals, and resultant coordinates are the same as those obtained with the Bursa – Wolf model. The shift parameters and associated r.m.s. values are different. The following logfiles show examples of the logfiles obtained from the two different models.

Normally, all transformation parameters will normally be computed.

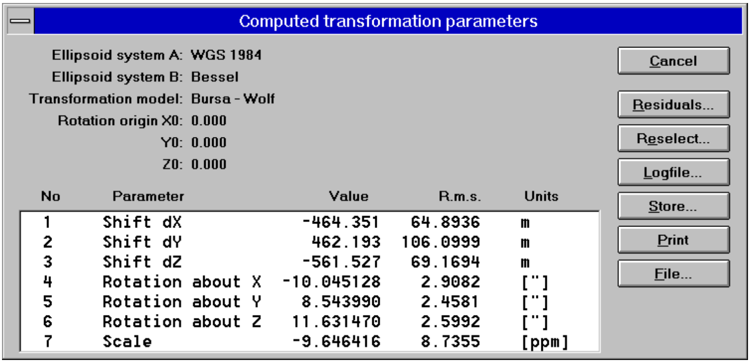
When you have matched all the required points press **Compute** to compute the transformation parameters.

9.6.6 Transformation Parameter Results

When you have computed a transformation, the results are presented. The appearance of the results depends upon which transformation approach has been used.

9.6.6.1 Classical Transformation results

If you have computed Classical Transformation parameters, the results appear as below.

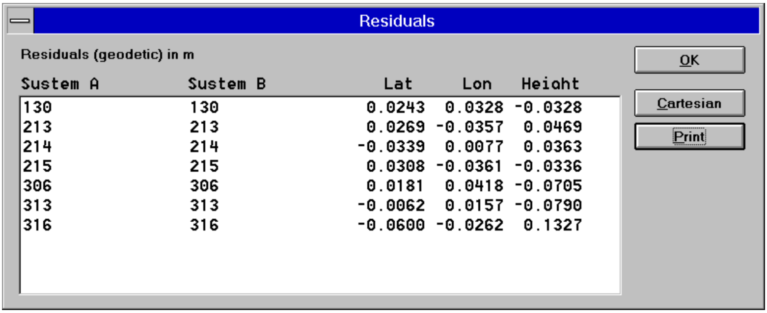


Computed transformation parameters

Ellipsoid system A: WGS 1984
Ellipsoid system B: Bessel
Transformation model: Bursa - Wolf
Rotation origin X0: 0.000
Y0: 0.000
Z0: 0.000

No	Parameter	Value	R.m.s.	Units
1	Shift dX	-464.351	64.8936	m
2	Shift dY	462.193	106.0999	m
3	Shift dZ	-561.527	69.1694	m
4	Rotation about X	-10.045128	2.9082	["]
5	Rotation about Y	8.543990	2.4581	["]
6	Rotation about Z	11.631470	2.5992	["]
7	Scale	-9.646416	8.7355	[ppm]

To obtain some idea of the accuracy of the computed transformation parameters in relation to the existing local coordinates press **Residuals**. The following dialogue box will appear. Press **Geodetic** to obtain the residuals in Lat, Lon, and Height.



Residuals

Residuals (geodetic) in m

System A	System B	Lat	Lon	Height
130	130	0.0243	0.0328	-0.0328
213	213	0.0269	-0.0357	0.0469
214	214	-0.0339	0.0077	0.0363
215	215	0.0308	-0.0361	-0.0336
306	306	0.0181	0.0418	-0.0705
313	313	-0.0062	0.0157	-0.0790
316	316	-0.0600	-0.0262	0.1327

The residuals are displayed for each point used in the transformation computation. What the residuals show is the amount by which the coordinate has moved in transforming from one system to another. They give an indication of points that are not homogenous within their network.

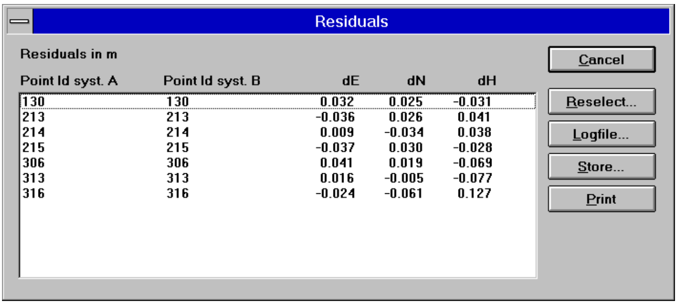
In most cases if the WGS84 coordinates are from GPS, have been processed in SKI and the results have resolved ambiguities (or over longer lines have good results), the network will be very homogenous.

Points that have moved by a large amount are displayed with large residuals. In the example given overleaf, point number 316 has rather large residuals, especially in the height component. This point could be taken out of the Transformation, and the Transformation parameters recomputed to give better, more accurate transformation parameters.

When you are satisfied with the Transformation Parameters press **Store** and enter a name for the Transformation Parameters. It is advised that you include in the name some reference to the way in which the parameters were computed. E.g. the name "Heer 7P Class BW" would indicate Heerbrugg network 7 parameter classical transformation using the Bursa-Wolf transformation model.

9.6.6.2 Results from other Transformation Approaches

With all other transformation approaches, when the **Compute** button has been pressed the residuals are displayed automatically in a dialogue box as below:



The residuals are displayed for each point used in the transformation computation. What the residuals show is the amount by which the coordinate has moved in transforming from one system to another. They give an indication of points that are not homogenous within their network.

In most cases if the WGS84 coordinates are from GPS, have been processed in SKI and the results have resolved ambiguities (or over longer lines have good results), the network will be very homogenous.

If large residuals are encountered, it is normally in the existing local coordinate network that the problem lies.

Points that have moved by a large amount are displayed with large residuals. In the example given overleaf, point number 316 displays larger residuals than the other points, especially in the height component. This point could be reselected as a position only component, and the transformation parameters recomputed to give better, more accurate transformation parameters.

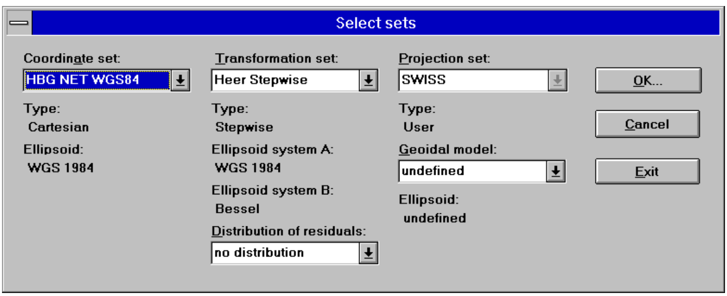
When you are satisfied with the Transformation Parameters press **Store** and enter a name for the Transformation Parameters. It is advised that you include in the name some reference to the way in which the parameters were computed. E.g. the name "Heer stepwise" would indicate Heerbrugg network stepwise transformation.

9.6.7 Transforming Coordinates

When the Transformation parameters for a particular area have been computed and stored you may use them to transform any point measured with GPS within the area enclosed by the transformation into local coordinates.

Import the GPS coordinates from SKI into Datum/Map as described in section 9.6.1.1

Return to the SKI main menu and select Datum/Map, Transform Coordinates. The following dialogue box will appear.

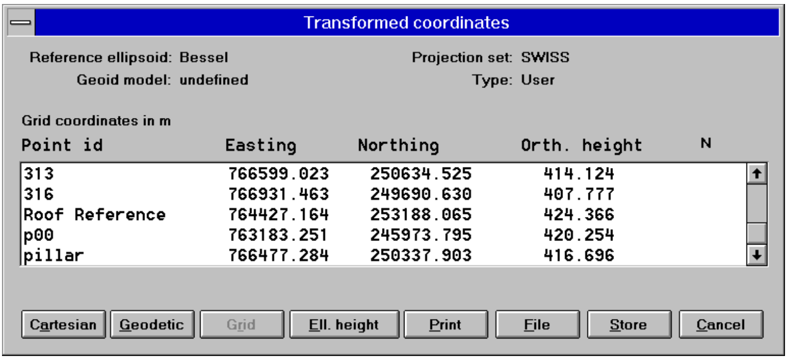


Select the Coordinate set that you wish to transform, the Transformation set that should be used to transform them and (in the case of a Classical Transformation set) a Projection set. Note that the Projection set will be automatically selected if a Stepwise Transformation set is selected.

If a Geoidal model is available and has been integrated into SKI, you may select it from the list in order to determine local ellipsoidal heights.

Distribution of residuals allows you to apply the residuals computed in the Transformation set to all points subsequently transformed using that transformation set. This means that all points subsequently transformed will be consistent with the existing coordinates.

When you are satisfied with the selection, press **OK**. The following dialogue box will appear containing the transformed coordinates.



You may now **Store** the coordinates in the Datum/Map database, **Print** them out or **File** the coordinates for further use.