Reference Book For

Topcon Positioning System Legacy E (GD Type) Post Processing and RTK GPS Training

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Note - All Document & Lecture Notes are in English.

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Union of Myanmar

Ministry of Agriculture and Irrigation

Irrigation Department

Reference Book
For
Topcon Positioning System Legacy E (GD Type)
Post Processing and RTK GPS Training

Irrigation Technology Center
2003

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DOCUMENT

Proposal for GPS Training

Background

ITC Project Phase II is implementing the project activities including the introduction of advanced measurement methods using GPS and remote sensing technology for the monitoring of reservoir and irrigation area. For this task, ITC Project Phase II received the first GPS training in February 2001 using GP-DX1 GPS . With the acquired knowledge and experience, System Development section undertook the Ngamoeyeik reservoir capacity measurement using GPS and echo-sounder and satellite image data. Now ITC received a new set of GPS (Legacy-E GD Type) in July 2002. For this new GPS set , ITC arranged to receive a training from Concordia International (TOPCON). ITC assumes that it will be more beneficial to invite staff personnel from Investigation Branch of Irrigation Department. Therefore the following facts and schedule are presented as the proposal for the training.

Objective

The main objective of the training course is to have the skill on GPS surveying works after learning the basic concepts of GPS survey, procedures for the different kinds of survey modes of GPS, maintaining and usage of the instruments and software according to the specified recommendation for the most effective and efficient way of practice. This knowledge and skill will extend benefits to the water management activities of ITC Project Phase II and further to the works of ID.

The Extensive Type test farm in Ngamoeyeik irrigation area will be used as the training field collecting point coordinates of the field. Those coordinates can be used for overlaying the CAD line drawing of extensive test farm to the satellite image. And then GIS will be made based on that data.

Lecturers

Staff personnel (one lecturere and two assistants) from Concordia International (TOPCON) will give the lecture to the staff of Investigation Branch and ITC Project Phase II. Total numbers of trainees will be 16 (10 persons from ITC Project Phase II and 6 persons from the Investigation Branch.

Expected Output

After finishing this training the trainees are expected to have the skill on GPS survey. The following knowledge and experience will be conveyed to them.

Basic knowledge of GPS Surveying
Base Line observation and data Processing
Network observation and data processing
RTK (Real Time Kinematic) observation and Data Processing
Feature Map of Extensive Type Test Farm

Recommended Participants' Level

Staff Officer or Sub-Assistant-Engineer with some basic computer knowledge

Expected Number of Participants

16 participants (6 persons from ITC and 10 persons from the Investigation Branch)

Duration : 10 days

Location : ITC (Bago)

Expected Time of Commencement: Third week of February, 2003

Teaching Method: Lecture and field survey (in the Extensive Test Farm)

Training Materials and Equipments

Lecture notes, GP-DX1 GPS and Legacy-E (GD Type) GPS, Total Station, PCCDU and Pinnacle (GPS Processing Software)

Subjects and Time Table :

Topcon Positioning System Legacy E (GD Type)

Post Processing and RTK GPS Training Schedule

Day	Time				Remark
	09:30 ~ 12:00		Lunch	13:30~16:30	
12.3.2003	Opening Ceremony	Pretest		How to work GPS?	Office
13.3.2003	Base line Observation and Post processing by using PCCDU and PINNACLE software				Office/Field
14.3.2003	Base line Observation and Post processing by using PCCDU and PINNACLE software				Field
15.3.2003	Saturday				Field
16.3.2003	Sunday				
17.3.2003	Full moon day of Tabaung				
18.3.2003	Base line Observation and Post processing by using PCCDU and PINNACLE software				
19.3.2003	GPS Network Observation and Network Processing				Office
20.3.2003	GPS Network Observation and Network Processing				Field
21.3.2003	What is RTK GPS How to work GPS? RTK Data Collection and Processing				Office
22.3.2003	What is RTK GPS How to work GPS? RTK Data Collection and Processing				Field
23.3.2003	Sunday				
24.3.2003	What is RTK GPS How to work GPS? RTK Data Collection and Processing				Field
25.3.2003	Discussions/Questions & Answers	Post test		Closing Ceremony	Office

Union of Myanmar

Ministry of Agriculture and Irrigation

Irrigation Department

Irrigation Technology Center

Completion Report
On
Legacy-E (GD Type) GPS Training

May, 2003

1. Introduction

ITC Project Phase II is implementing the project activities including the introduction of advanced measurement methods using GPS and remote sensing technology for the monitoring of reservoir and irrigation area. For this task, ITC Project Phase II received the first GPS training in February 2001 using GP-DX1 GPS . With the acquired knowledge and experience, System Development section undertook the Ngamoeyeik reservoir capacity measurement using GPS and echo-sounder and satellite image data. Now ITC received a new set of GPS (Legacy-E GD Type) in July 2002. For this new GPS set , ITC arranged to receive a training from Concordia International (TOPCON). ITC assumes that it will be more beneficial to invite staff personnel from Investigation Branch of Irrigation Department. Therefore eight participants from Investigation Branch attended in this training together with the eight participants (counterparts) of ITC Project Phase II.

2. Objective

The main objective of the training course is to have the skill on GPS surveying works after learning the basic concepts of GPS survey, procedures for the different kinds of survey modes of GPS, maintaining and usage of the instruments and software according to the specified recommendation for the most effective and efficient way of practice. This knowledge and skill will extend benefits to the water management activities of ITC Project Phase II and further to the works of ID.

3. Expected outputs

Participants can acquire basic knowledge about GPS technology, GPS data collection and Data processing techniques. And they can utilize their knowledge in their practical works.

4. Duration and location

According to the agreement between Concordia International Co., Ltd (TOPCON) and ITC, training period was 10 days net duration. And training was conducted at ITC.

5. Participants

Sr. No.	Name	Designation	Office
1.	U Myo Aung	Staff Officer (Civil)	System Development Section, ITC
2.	U Kyaw Lin Oo	Staff Officer (Civil)	System Development Section, ITC
3.	U Aung Naing	Staff Officer (Civil)	Training Section, ITC
4.	U Zaw Zaw Lat	Staff Officer (Civil)	Irrigation Information Management Section, ITC
5.	Daw Aye Aye Hlaing	Staff Officer (Civil)	Training Section, ITC
6.	U San Win Naing	Staff Officer (Civil)	Water Management II Section, ITC
7.	U Htay Aung Tint	Staff Officer (Civil)	Water Management I Section, ITC
8.	U Myint Soe	Staff Officer (Civil)	Investigation Branch (Yangon)
9.	U Khin Maung Htay	Staff Officer (Civil)	Investigation Branch (Yangon)
10.	U Myint Lwin	Staff Officer (Civil)	Investigation Branch (Yangon)
11.	U Khin Maung Tint	Staff Officer (Civil)	Investigation Branch (Meikhtila)
12.	U Moe Aung	Special SAE	Investigation Branch (Meikhtila)
13.	U Kyaw Nyunt	Special SAE	Investigation Branch (Meikhtila)
14.	U Thant Zin	Special SAE	Investigation Branch (Meikhtila)
15.	Daw Phyu Phyu	SAE	Investigation Branch (Yangon)
16.	U Aye Min	SAE	Water Management I Section, ITC

6. Subjects

1. How to work GPS?
2. Base line Observation and Post processing by using PCCDU and PINNACLE software
3. GPS Network Observation and Network Processing
4. What is RTK GPS How to work GPS? RTK Data Collection and Processing

7. Training Program

7.1 Teaching Method

Lecture and field survey (in the ITC compound and Extensive Test Farm)

7.2 Training Materials and Equipments

Lecture notes, GP-DX1 GPS and Legacy-E (GD Type) GPS, Total Station, PCCDU and Pinnacle (GPS Processing Software)

Topcon Positioning System Legacy E (GD Type)
Post Processing and RTK GPS Training Schedule

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13.3.2003	Base line Observation and Post processing by using PCCDU and PINNACLE software				Office/Field (ITC Bago)
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15.3.2003	Saturday				
16.3.2003	Sunday				
17.3.2003	Full moon day of Tabaung				
18.3.2003	Base line Observation and Post processing by using PCCDU and PINNACLE software				Field(ITC Bago)
19.3.2003	GPS Network Observation and Network Processing				Office
20.3.2003	GPS Network Observation and Network Processing				Field(ITC Bago)
21.3.2003	What is RTK GPS How to work GPS? RTK Data Collection and Processing				Office
22.3.2003	What is RTK GPS How to work GPS? RTK Data Collection and Processing				Field(Extensive test farm Hlegu)
23.3.2003	Sunday				
24.3.2003	What is RTK GPS How to work GPS? RTK Data Collection and Processing				Field(ITC Bago)
25.3.2003	Discussions/Questions & Answers	Post test		Closing Ceremony	Office

7.3 Activities

Basic principals and application procedures about GPS survey were given in classroom. Practical observation were made in ITC compound. ITC have two numbers of GP-DX1 receiver and two numbers of Legacy-E (GD type) receiver. And participants were divided into four observation groups. Using observed data of each group base line processing and network observation were made. For RTK (Real Time Kinematics) two numbers of Legacy-E (GD type) receivers were used. The Extensive Type test farm in Ngamoeyeik irrigation area was used as the training field as a workshop applying static base line measurement and RTK survey mode. For reduced level value, we took the BM in Phaunggyi Hospital Compound.

8. Lecturers

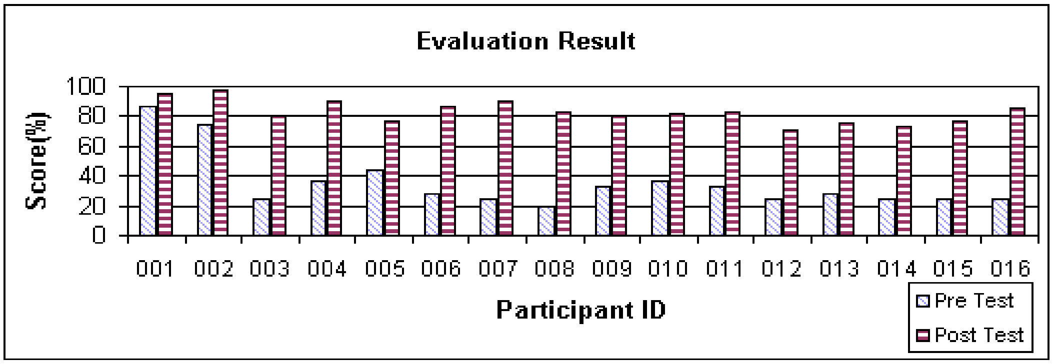
Staff personnel (one lecturer and one assistant) from Concordia International (TOPCON) gave the lecture in this training.

9. Evaluation

9.1 Training Effects

System Development section made pre test and post test questionnaire to evaluate this training. Results are tabulated and graphed below.

Participant ID	Pre Test	Post Test
001	86	95
002	75	98
003	25	81
004	36	90
005	44	77
006	28	87
007	25	90
008	19	83
009	33	80
010	36	82
011	33	83
012	24	71
013	28	76
014	25	73
015	24	77
016	24	85



The participants acquired the following knowledge and experience through this training.
- Basic knowledge of GPS Surveying
- Base Line observation and data Processing (**Result sheet- see attachment-1**)
- Network observation and data processing (**Result sheet- see attachment-2**)
- RTK (Real Time Kinematic) observation and Data Processing
- FeatureMap of a portion of Extensive Type Test Farm between WC7 & WC8 (**Result sheet- see attachment-3**)

9.2 Evaluation on Training Programs by Participants

According to the answer in participants' questionnaires they said this training is useful for them. Most of them satisfied on this training. And some of them asked to extend the training period. Some participants requested to share more computer application time. Some participants requested to give more practical works.

9.3 Evaluation on Training Programs by System Development section

As per score of post test and their results, participants received knowledge about basic application of GPS instruments (Legacy-E and GPDX1), fundamental of GPS survey and basic theory of GPS technology.

9.4 Evaluation on Training Programs by Training section

This is a successful training. Participants were found to be interested in GPS training Course, not only classroom lectures but also practical field works. Lecturer gave instructions clearly about using GPS instruments and close instruction for survey practice and procedures. Participants cannot understand editing the map during this training duration.

10. Recommendation

10.1 Recommendation by Training Section

It is better to explain field schedule before field observation. Participants should have to understand the basic computer knowledge and basic survey knowledge. It is better to extend training duration for better skill and practices.

10.2 Recommendation by System Development section

1. Some software require hard lock key and it was a constraint in using application software. In that case at one time only one participant could practically use computer while the rest were watching on projector screen.

2. Coordinate system and Geoid editor, one of the tools in Pinnacle Software, a post processing software for Legacy-E (GD type) GPS instrument, can specify the parameters. These are called 7 parameters and one coordinate projection system to another can be transformed by using these parameters if we have three know points. This tool is useful to transform from WGS84 system (default system of GPS receiver) to Lambert Conical Orthomorphic projection system (currently used in Myanmar). Then parameters for Ngamoeyeik irrigation area can be specified if we have three known points around the region.

Attachment-1

Base line processing for 4 stations

ADJUSTMENT SUMMARY	
Item Name	**Item Value**
SubNet	
Name	Session
Number of points	4
Number of unknowns	9
Degree of freedom	9
Declared adjustment type	with fixed and weighted points
Aposteriori standard error of unit weight	0.851
Adjustment Date and Time	13.Mar.03 13:32:11

SUBNET 'Session' POINTS: ADJUSTED COORDINATES in WGS84(BLH)

#	Point Name	Coordinates			Sigmas(mm)			Corr.(%)		
		Latitude	Longitude	height(m)	s(N)	s(E)	s(U)	N-E	N-U	E-U
1	STN1	17°18'52.61355"N	96°27'13.18772"E	-11.3414	0.3	0.4	0.9	16	2	27
2	STN2	17°18'53.24276"N	96°27'13.21186"E	-11.2650	0.4	0.4	1.1	17	7	29
3	STN3	17°18'53.13536"N	96°27'14.85435"E	-11.3457	0.0	0.0	0.0	0	0	0
4	STN4	17°18'53.63685"N	96°27'16.39870"E	-11.1472	0.4	0.4	1.0	17	1	28

SUBNET 'Session' POINTS: ADJUSTED COORDINATES in UTMN(Grid, Zone Zone_47 : 96E to 102E)

#	Point Name	Coordinates			Sigmas (mm)			Corr.(%)		
		Northing (m)	East (m)	Height (m)	s(N)	s(E)	s(U)	N-E	N-U	E-U
1	STN1	1916150.6473	229342.1585	-11.3414	0.3	0.4	0.9	16	2	27
2	STN2	1916169.9893	229343.1279	-11.2650	0.4	0.4	1.1	17	7	29
3	STN3	1916166.0443	229391.6067	-11.3457	0.0	0.0	0.0	0	0	0
4	STN4	1916180.8639	229437.4337	-11.1472	0.4	0.4	1.0	17	1	28

SUBNET 'Session' PROCESSED VECTORS (Distance-Azimuth-Elevation)

#	Stations	Coordinates			Sigmas (mm)			Corr.(%)		
	from - to	Distance(m)	Azimuth	Elevation	s(D)	s(A)	s(E)	D-A	D-E	A-E
1	STN1-STN4	99.9016	71°38'42.52"	0°06'44.46"	0.6	0.6	1.6	-11	17	15
2	STN2-STN1	19.3563	182°06'37.53"	- 0°13'08.30"	1.0	1.0	2.6	17	-11	-33
3	STN2-STN3	48.6145	93°53'37.76"	- 0°05'38.72"	0.7	0.7	1.9	-16	30	-11
4	STN2-STN4	94.8827	82°39'50.46"	0°04'10.92"	0.7	0.6	1.6	-20	20	-2
5	STN3-STN1	51.7634	251°56'47.83"	0°00'20.45"	0.5	0.5	1.3	-8	-25	-6
6	STN3-STN4	48.1395	71°19'18.34"	0°14'05.01"	0.7	0.6	1.9	-9	32	11
Mean weight matrix's estimations:					**0.7**	**0.6**	**1.6**	**-12**	**8**	**-1**

Attachment-2

Network processing for 6 stations

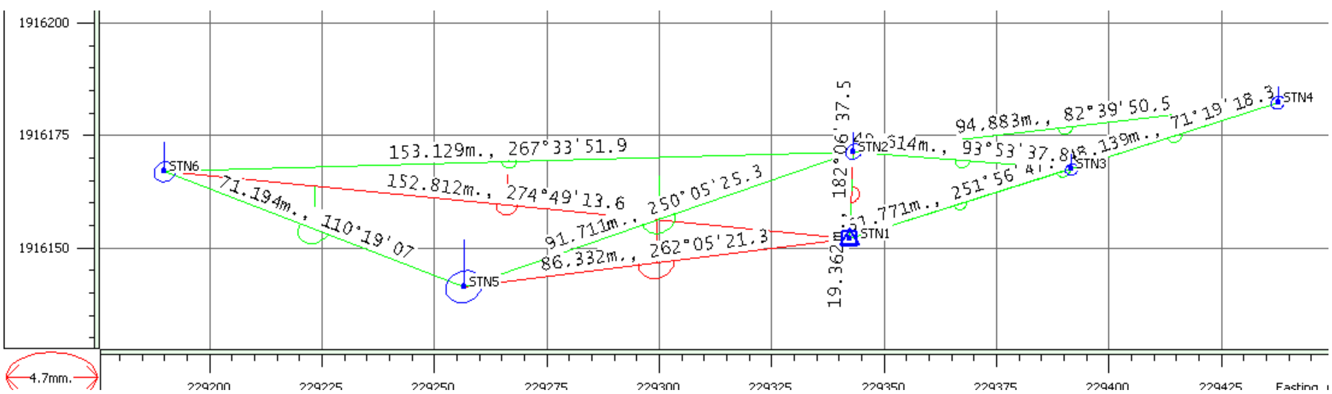
ADJUSTMENT SUMMARY	
Item Name	**Item Value**
SubNet	
Name	Session
Number of points	6
Number of unknowns	15
Degree of freedom	12
Declared adjustment type	with fixed and weighted points
Aposteriori standard error of unit weight	0.751
Adjustment Date and Time	18.Mar.03 10:43:53

SUBNET 'Session' POINTS: ADJUSTED COORDINATES in WGS84(BLH)

#	Point Name	Coordinates			Sigmas(mm)			Corr.(%)		
		Latitude	Longitude	height(m)	s(N)	s(E)	s(U)	N-E	N-U	E-U
1	STN1	7°18'52.66072"N	96°27'13.18976"E	-14.0635	.0	0.0	0.0	0	0	0
2	STN2	17°18'53.28993"N	96°27'13.21390"E	-14.0182	0.4	0.4	1.0	17	5	27
3	STN3	17°18'53.18253"N	96°27'14.85640"E	-13.9574	0.3	0.3	0.8	16	2	27
4	STN4	17°18'53.68402"N	96°27'16.40075"E	-13.9004	0.3	0.3	0.9	17	-3	24
5	STN5	17°18'52.27408"N	96°27'10.29399"E	-15.0187	0.8	0.9	2.5	16	3	1
6	STN6	17°18'53.07824"N	96°27'08.03306"E	-15.0311	0.5	0.5	1.6	10	4	3

SUBNET 'Session' POINTS: ADJUSTED COORDINATES in UTMN(Grid, Zone Zone_47 : 96E to 102E)

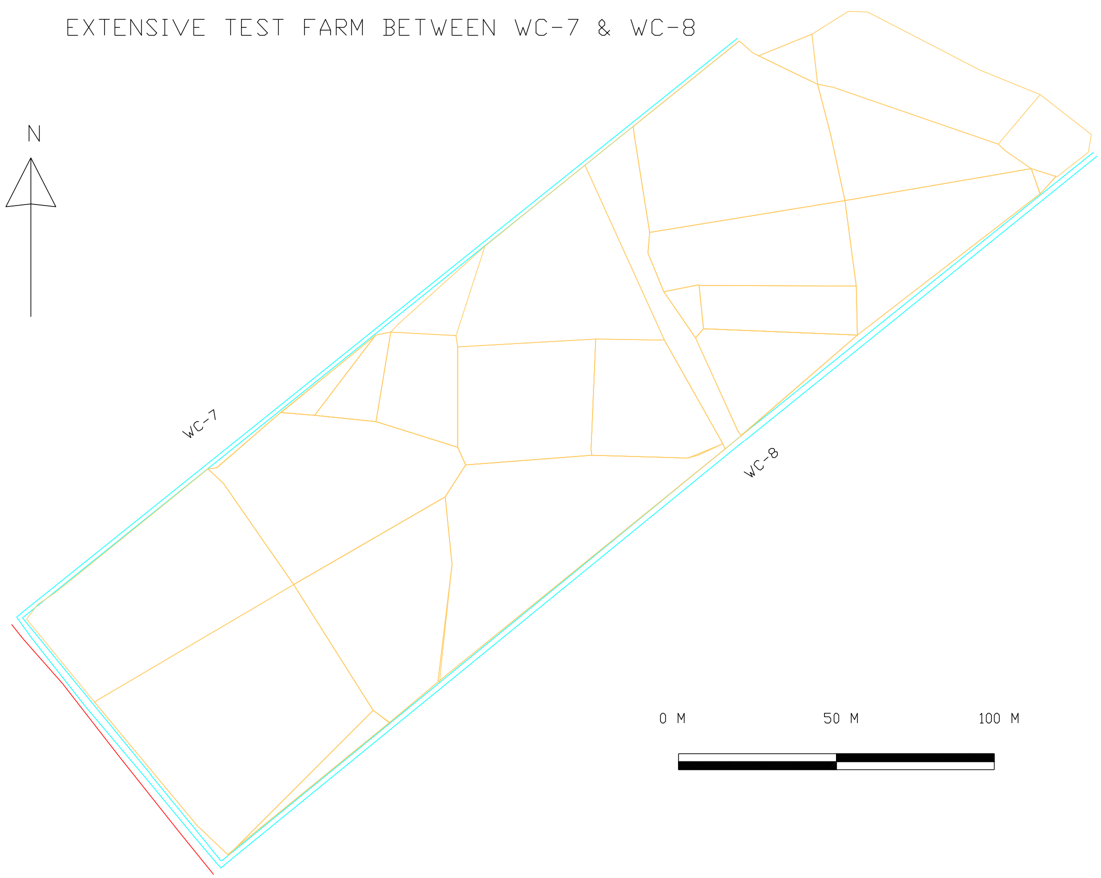
#	Point Name	Coordinates			Sigmas (mm)			Corr.(%)		
		Northing (m)	East (m)	Height (m)	s(N)	s(E)	s(U)	N-E	N-U	E-U
1	STN1	1916152.0973	229342.2381	-14.0635	0.0	0.0	0.0	0	0	0
2	STN2	1916171.4393	229343.2074	-14.0182	0.4	0.4	1.0	17	5	27
3	STN3	1916167.4943	229391.6862	-13.9574	0.3	0.3	0.8	16	2	27
4	STN4	1916182.3139	229437.5133	-13.9004	0.3	0.3	0.9	17	-3	24
5	STN5	1916141.3386	229256.5339	-15.0187	0.8	0.9	2.5	16	3	1
6	STN6	1916166.9550	229190.0690	-15.0311	0.5	0.5	1.6	10	4	3



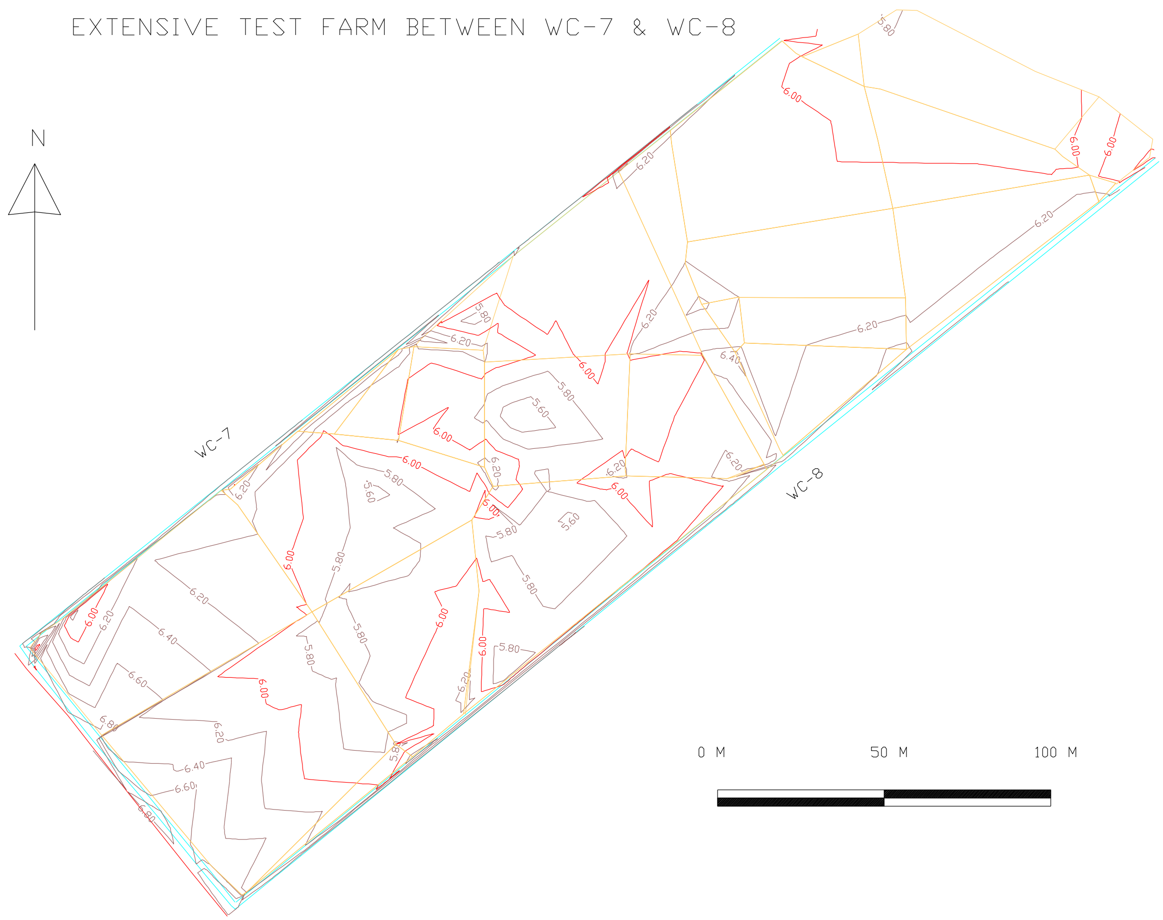
SUBNET 'Session' PROCESSED VECTORS (Distance-Azimuth-Elevation)

#	Stations	Coordinates			Sigmas (mm)			Corr.(%)		
	from - to	Distance(m)	Azimuth	Elevation	s(D)	s(A)	s(E)	D-A	D-E	A-E
1	STN1-STN4	99.9015	71°38'42.53"	0°05'40.24"	0.6	0.6	1.6	-11	17	15
2	STN1-STN5	86.3317	262°05'21.31"	- 0°36'18.02"	1.6	1.3	4.3	-11	6	8
3	STN1-STN6	152.8098	274°49'13.63"	- 0°20'35.38"	0.6	0.5	1.9	-1	16	2
4	STN2-STN1	19.3562	182°06'37.53"	- 0°07'36.88"	1.0	1.0	2.6	16	-11	-33
5	STN2-STN1	19.3617	182°07'37.23"	- 0°16'24.16"	0.4	0.4	1.3	-2	-10	7
6	STN2-STN3	48.6144	93°53'37.76"	0°04'21.70"	0.7	0.7	1.9	-17	30	-11
7	STN2-STN4	94.8827	82°39'50.46"	0°04'10.92"	0.7	0.6	1.6	-20	20	-2
8	STN2-STN5	91.7107	250°05'25.27"	- 0°37'29.75"	1.6	1.3	4.2	-5	1	4
9	STN2-STN6	153.1294	267°33'51.88"	- 0°22'47.09"	0.5	0.4	1.7	2	19	4
10	STN3-STN1	51.7635	251°56'47.83"	- 0°06'59.52"	0.5	0.5	1.3	-8	-25	-6
11	STN3-STN4	48.1392	71°19'18.35"	0°03'58.72"	0.7	0.6	1.9	-9	31	11
12	STN6-STN5	71.1947	110°19'06.99"	0°00'32.67"	1.4	1.4	3.9	-21	-4	-2
Mean weight matrix's estimations:					**0.7**	**0.6**	**1.8**	**-7**	**6**	**2**

Attachment-3



EXTENSIVE TEST FARM BETWEEN WC-7 & WC-8



PRE TEST for GPS Training
Questionnaire

Trainee's ID

1. GPS is the acronym of G _ _ _ _ _ P_ _ _ _ _ _ _ _ _ _ _ _ S _ _ _ _ _.

2. Have you ever had a GPS survey before? If you had , please name it and desirable the model & methods (survey modes) you used. Yes (or) No.

3. Have you ever heard the following terms used in GPS survey. (Tick "Yes" or "No")

(i)	Ellipsoid	Yes / No
(ii)	Geoid	Yes / No
(iii)	Datum	Yes / No
(iv)	Grid	Yes / No
(v)	Easting, Northing	Yes / No
(vi)	False Eeasting, False Northing	Yes / No
(vii)	Longitude, Latitude	Yes / No
(viii)	Projection	Yes / No
(ix)	Conic Projection	Yes / No
(x)	Cylindrical Projection	Yes / No
(xi)	Lambert Projection	Yes / No
(xii)	Transverse Mercator Projection	Yes / No
(xiii)	UTM	Yes / No
(xiv)	Ephemeris	Yes / No
(xv)	Static Survey	Yes / No
(xvi)	Kinematics Survey	Yes / No
(xvii)	RTK	Yes / No

4. Describe some components of a GPS Unit.

5. What does "post-processing " mean?

6. Describe some advantages and disadvantages of GPS survey over the conventional land survey method.

Advantages	Disadvantages

POST TEST for GPS Training
Questionnaire

Trainee's ID

1. GPS is the acronym of G _ _ _ _ _   P_ _ _ _ _ _ _ _ _ _ _   S _ _ _ _ _.

2. Have you ever had a GPS survey before? If you had , please name it and desirable the model & methods (survey modes) you used.   Yes (or) No.

3. Have you ever heard the following terms used in GPS survey. (Tick "Yes" or "No")

(i)	Ellipsoid	Yes / No
(ii)	Geoid	Yes / No
(iii)	Datum	Yes / No
(iv)	Grid	Yes / No
(v)	Easting, Northing	Yes / No
(vi)	False Eeasting, False Northing	Yes / No
(vii)	Longitude, Latitude	Yes / No
(viii)	Projection	Yes / No
(ix)	Conic Projection	Yes / No
(x)	Cylindrical Projection	Yes / No
(xi)	Lambert Projection	Yes / No
(xii)	Transverse Mercator Projection	Yes / No
(xiii)	UTM	Yes / No
(xiv)	Ephemeris	Yes / No
(xv)	Static Survey	Yes / No
(xvi)	Kinematics Survey	Yes / No
(xvii)	RTK	Yes / No

4. Describe some components of a GPS Unit.

5. What does "post-processing " mean?

6. Describe some advantages and disadvantages of GPS survey over the conventional land survey method.

Advantages	Disadvantages

7. Is this training useful for you? (Yes/No)

8. Please note down your overall comment on this training.

LECTURE NOTES

TOPCON
POSITIONING SYSTEMS

Pinnacle™
Reference Documentation Suite

IMPORT
User's Manual

This documentation reflects the April 4, 2001 version of Pinnacle 1.0

Last revised July 31, 2001

USER'S NOTICE

Specifications are subject to change without notice. TPS provides this manual 'as is' without warranty of any kind, either express or implied, including but not limited to the implied warranties or conditions of merchantability or fitness for a particular purpose.
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1. *Introduction*

Pinnacle's ***Import*** is a module intended to input (*import*) raw measurements, satellite orbits and vectors and points files into a specific *network* of the given project.

There are two alternative ways in which data can be imported into Pinnacle.
The first way is to import data as 'post-processing files' residing either on a local or LAN drive, or residing on a remote server accessible via an appropriate web protocol. For details refer to 2 and 3.
The second way is download raw data measurements ('log-files') from the receiver memory directly into the Pinnacle project's database. For more information on this please see 4.

To run ***Import***, the user must go to the *Networks* panel[1] in the main project window and right-click on the desired network item. A window will pop up as shown in Figure 1-1:

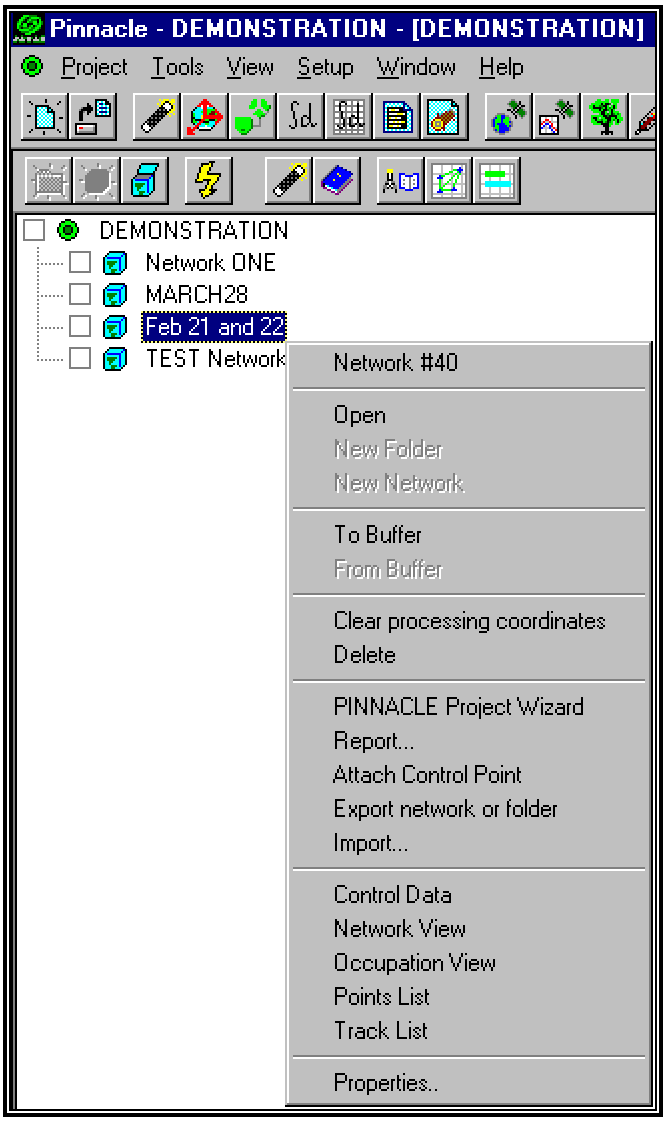


Figure 1-1

[1]) This is the left-hand-most panel in the project window. In this panel the user will see the list of networks available in the given project.

After the user selects the *Import…* option from this menu, the *Import* window will be opened.

If the user opens this window for the first time, it will be empty. If some *data channels* have already been specified, the user will see a list of the existing data channels (see Figure 1-2).

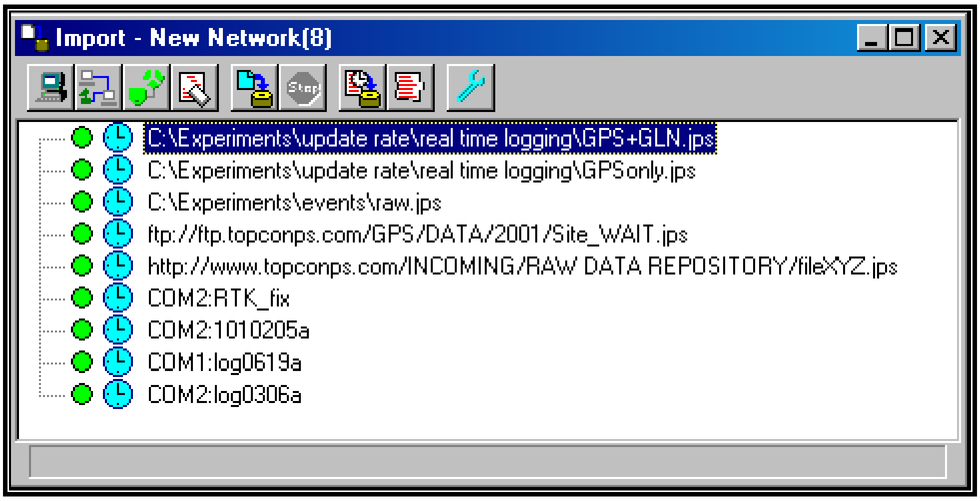


Figure 1-2

As seen from Figure 1-2, a *data channel* can be

- a file on a local or network drive, or
- a URL accessible via FTP or HTTL, or
- a receiver log-file.

Data channels established in this way will hereafter be referred to as an *import schedule*. Normally, such a schedule will apply to the given specific network only. There are some exceptions to this rule though. For example, ephemeris data (either broadcast or precise orbits) imported into a specific network will be accessible *throughout the project* (in other words, the imported orbits will be shared by all of the project's networks). Note, however, that such *ephemeris* data channels will be explicitly shown only in the *original* import schedule where they have been specified first.

2. *Adding Local Files*

To add files to an *import schedule*, press the button (*Local*). A standard ‘File|Open’ dialog box will appear allowing the user to select one or more files either from the local system’s drive or from the network neighbourhood. The *Files of type:* combobox will list all of the file types that Pinnacle can import.

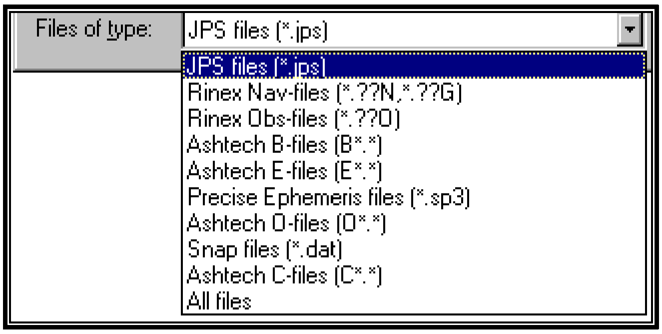


Figure 2-1

Note that this list will actually depend on what specific set of *Import Filters* is available in the given version of Pinnacle. For more details about *Import Filters,* see 6.

3. *Adding Remote Sources as Data Channels*

To add a remote data source to the import schedule, press the button (*Remote*) and enter the desired URL (Universal Resource Locator, or Internet address) exactly as it is entered when running Internet browsers:

`<protocol>://<host name>/<file location>`

For example: `ftp://ftp.mycompany.com/GNSS/Data/2001/Site1.JPS`

If the site or directory is password protected, you will also need to specify the login and password as part of the URL:

`<protocol>://<login>:<password>@<host name>/<file location>`

For example:
`ftp://joe:secretword@ftp.mycompany.com/GNSS/Data/2001/Site1.JPS`

Note that Pinnacle will first launch an external application to retrieve the desired remote file, then put that file's copy into the *cache folder* and finally handle the copy as if it is a local file accessible via the *Local* button. To find out about where your *cache folder* resides and what application is used to download remote files, see 8.

To import a file located somewhere in the network neighborhood, the user will specify the URL in this way:

`file://<computer>/<folder name>/<file name>`

To import a file from a local drive, the URL must be specified as follows:

`file:<drive letter>:\<folder name>\<file name>`

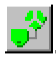
For example:
`file:C:\TopconPS\projects\MCS\RINEX\Session1\SN11084U.01O`

There is an essential difference between this way of adding a local file to an *import schedule* and the approach described in 2. When a local file to be added to a schedule is treated as a remote source, then

1) This file's copy will be created in *Cache Folder* and,
2) This file may or may not be available on the local system at the time of planning the *import schedule*.

4. *Download Receiver Files Directly into Pinnacle*

To download raw data measurements from a receiver directly into a Pinnacle project's network, take the following steps:

1) Connect the receiver to the computer with a serial cable. To do this, the user can use any two of the free serial ports available on the receiver and computer respectively.
2) After the cable is properly connected, the user will click on the button . The *Receiver Files* dialog window will appear on the screen.
3) The user will select the correct port from the *Select COM port* listbox and press the *Connect!* button. After Pinnacle has polled the receiver and accessed the file system information, the user will see a list of the logfiles stored in the receiver memory (see Figure 4-1).

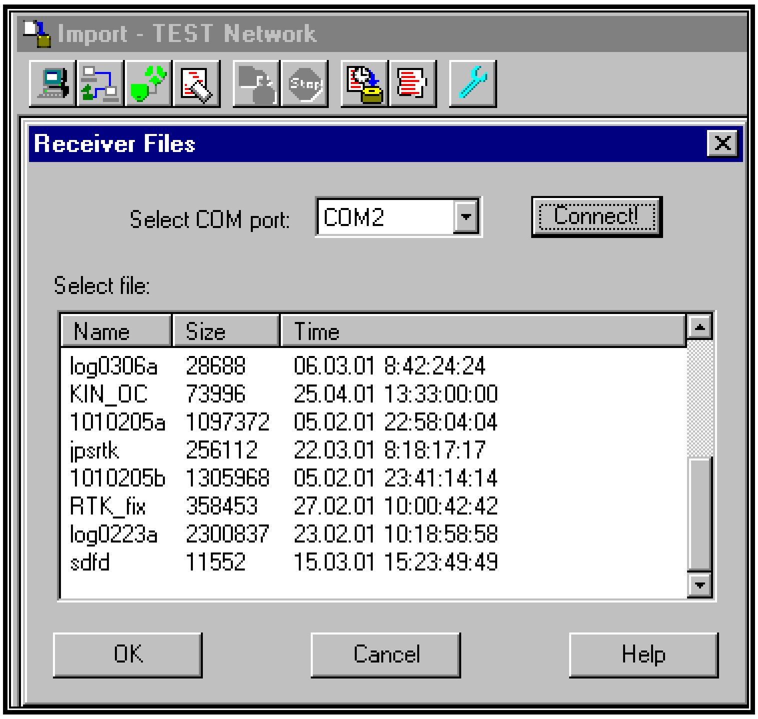


Figure 4-1

4) Finally, the user will select the logfiles imported and press the *OK* button. These logfiles will be added to the import schedule as new data channels (see the four bottom-most channels in Figure 1-2).

5. *Operating an Import Schedule and Data Channels*

After the user has specified the desired channels, the *import* window will look like this:

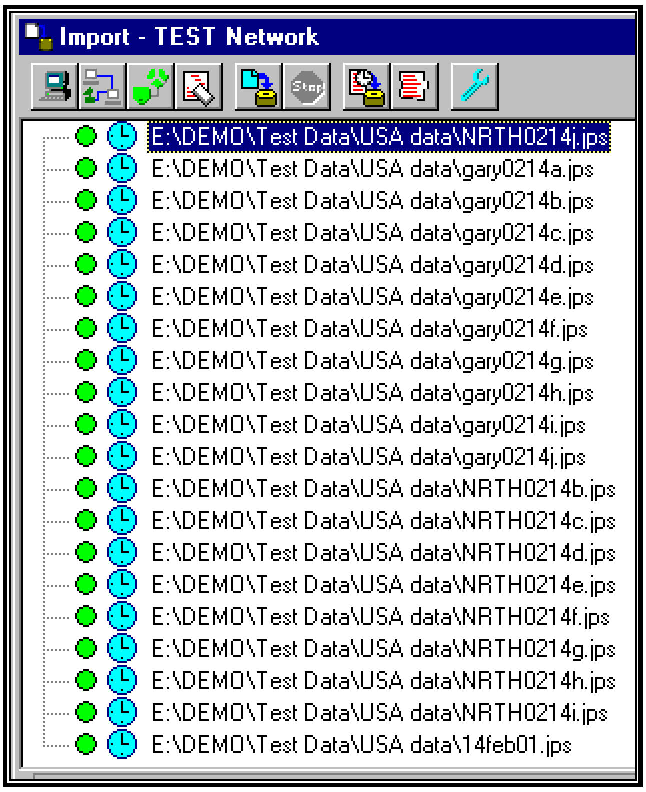


Figure 5-1

This window will show all of the channels that have been established so far. Also, it will provide some additional information on the channels.

5.1. Enabling/Disabling Data Channels

Green circles (●) will indicate *enabled* channels. If the user doesn't need a channel to be activated the next time the schedule is run, (s)he can *disable* this channel by clicking on the corresponding green circle or by right-clicking on the channel item in the list and then selecting the *Disable* option from the pop-up menu. The circle will turn red either way. To re-enable the channel, click on the red circle or select '*Enable'* from the pop-up menu. While the channel is active, its circle will be marked in yellow, and the user will be unable to enable or disable this channel during this time.

5.2. Status Icons

The clock icons ( ) next to the channels will indicate that these channels are ready for activation. As the channels are processed and their status changes, the channels' icons will be changing too. The following table shows all of the possible channel status icons:

	File successfully imported into the project's database
	There was an error – file cannot be opened
	An error occurred while handling the file. This file may contain corrupt data
	Channel activation is deferred according to the import schedule, and then the user aborted waiting on data
	An internal error occurred while importing the file
	This file has already been loaded into this network
	Channel is activated, import is in progress
	Additional information

Table 1

When the *import schedule* is activated, the *Import* window will show messages indicating the status of the corresponding *channels* and the progress of data importing and occupation filtering. Such messages are also marked with the appropriate icons from Table 1.

5.3. Clearing Schedule

To clear an *import schedule*, press the button (*Clear Schedule*). All *Data Channels* will be removed from the *import schedule*. Alternatively, you can right-click somewhere in the *Import* window and select the *Clear Schedule* option from the pop-up menu. Note that this command remains disabled (and the corresponding button remains grayed out) while data import is in progress.

5.4. Activating Schedule Manually

To activate all the channels, press the button (*Start*), or select the *Start* option from the pop-up menu that appears after right-clicking somewhere in the *Import* window. This will override any particular schedule assigned to the channels before so that these channels will be activated immediately. See 5.6 for how to assign a schedule to a channel.

If data import is in progress, the *Start* command is disabled and the corresponding button is grayed out.

5.5. Aborting Import

Press the button (*Skip the rest*) to abort import. If a file is being loaded when this button is pressed (note that the progress indicator in this window's status bar will show the status of data importing), Pinnacle will first complete the loading of this file and only then will deactivate the rest of the files from the schedule. Besides, all of the channels that have been deferred will stop waiting on data. Note that this command will also be available through the pop-up menu. Until data import starts, this command will remain disabled (the corresponding button will be grayed out).

5.6. Channel Properties

Right-click on the desired *data channel* and select the *Properties* option from the pop-up menu.

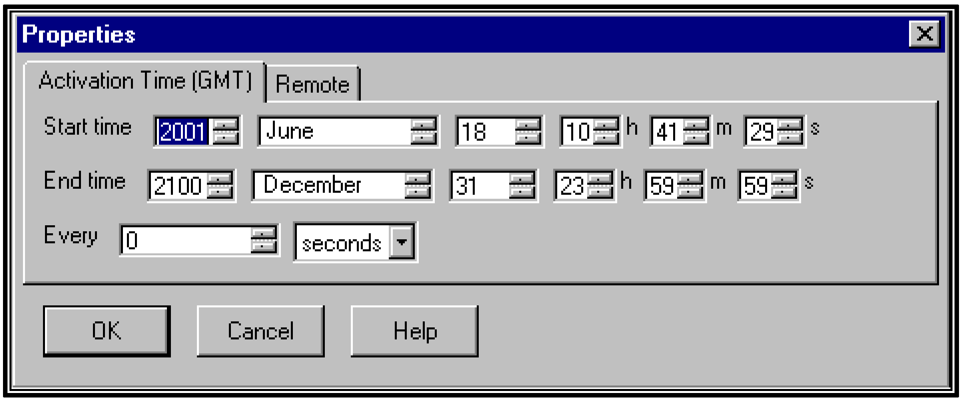


Figure 5-2

In this dialog window the *Start time* and *End time* parameters will indicate the time period over which the channel is assumed activated, but this will hold true only if *data import* is run via the *Make* command. On the other hand, if activated via the *Start* button, the *Import* tool will disregard the above two settings. By default, the *Start time* is defined as the time when the channel is added to the schedule.
Through the *Every* spinbox, the user can set the channel's *activation period*. This feature is very helpful when the user needs to download from a remote source (e.g., an ftp server) a file which is known to be periodically updated.

If a data channel is created for a local or LAN file by using the *Local* button, the channel's *Properties…* window will have only the *Activation Time (GPS)* tab. Otherwise the *Properties…* window will have two tabs, *Activation Time (GPS)* and *Remote* (see Figure 5-3). The latter is intended to edit the channel's URL if necessary.

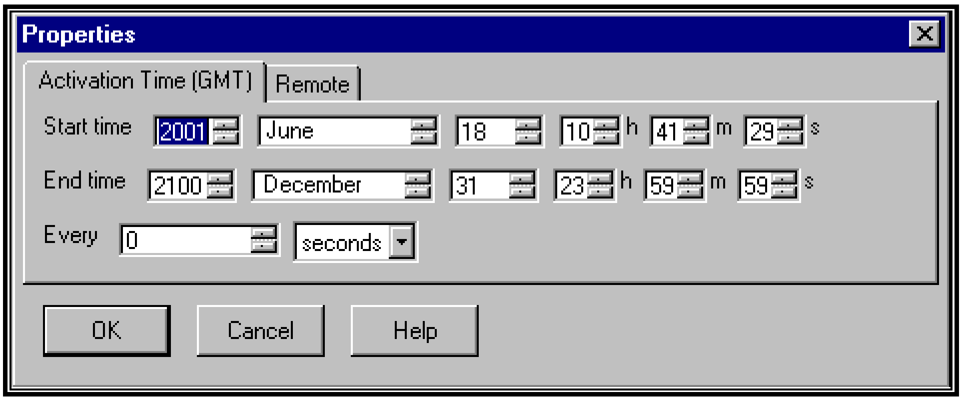


Figure 5-3

6. *Import Filters*

The Pinnacle *Import* module is able to automatically recognize several ‘friendly’ file formats. First, the *Import* module will check whether the file imported is in a compressed format. Pinnacle is capable of recognizing packed files created with **zip**, **gzip**, and **Z**. Once the import file is identified as compressed data, the *Import* module will first unpack it and then forward the decompressed data on to the *input filters*.

The input filters are a set of dynamically loaded modules. The user can check what specific filters are available in Pinnacle by examining the configuration file PINNACLE.INI, which is located in the Windows directory, or by running Pinnacle's configuration utility CONFIG.EXE (see the directory where Pinnacle's binaries are kept).

When importing a file, the *Import* module will ‘load’ the input filters one by one until a filter capable of reading this import file is found. Then this filter will read the imported file's contents into the project database. If none of the input filters can recognize the import file, then the ‘*Format not recognized*’ message will be displayed.
The current version of Pinnacle[2] allows the import of the following file formats:

- JPS post-processing files. These files are created by PC-CDU based on the receiver log-files. Unlike all the other file formats supported, these files are normally ‘***self-sufficient***’ including ***<u>all</u>*** data necessary for Pinnacle processing vectors and trajectories.[3]
- RINEX observation and navigation (GPS and GLONASS) files.
- Ashtech B-, E- files. These are observation and ephemeris files, respectively.
- Ashtech O-files. Unlike the above-mentioned files, O-files provide processed vectors rather than raw measurements or ephemerides.
- SNAP points and vectors files. These ASCII file formats relate to the SNAP adjustment package.
- NGS precise orbit files (SP3 format only).

Note that after an imported file's contents have been successfully imported into the project database, the user may remove this file from the disk if necessary.

[2]) as of April, 2001
[3]) Assuming the imported JPS files are based on the default or a richer set of JPS messages (see the GRIL).

7. *Occupation Filtering*

After data importing via the activated channels is over, the '*Filter occupation*' submodule will start running. For each occupation and for each measurement time (*epoch*) of this occupation, Pinnacle will compute the *single-point* (or *absolute*) positions. Also, at this stage Pinnacle will check whether the project database contains adequate ephemeris information and enough satellite measurements, etc. For example, if the antenna height and/or type is unknown (unspecified) for the occupation, there will be a warning generated and displayed in the '*Import'* window (see Figure 7-1).

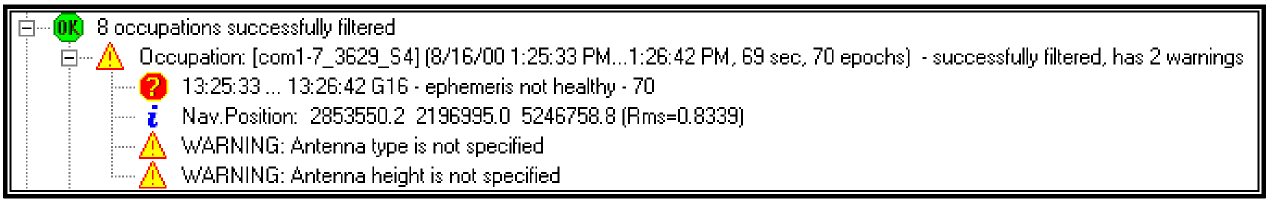


Figure 7-1

Note that unlike JPS files and Ashtech B-files, RINEX observation files do not contain single-point positions. To compensate for the lack of the absolute coordinates in the files, the pre-processing submodule *RawFilter* will compute point positions on its own using the raw measurements and ephemerides from the RINEX observation and navigation files, respectively. These absolute positions will then be stored in the project database.

The user should keep in mind that when inputting occupations the corresponding data will first be forwarded to a special session named *_Import*. If successfully filtered, these data will then be put either into the *planned* sessions or predefined sessions named *Session.* If there is a session with the name *Session* already, Pinnacle will use the session name *Session(1)*, etc.

If the raw data imported to the project lack some of the ephemerides necessary for successful *occupation filtration,* than this stage will be not complete and Pinnacle will report the following messages (see Figure 7-2):

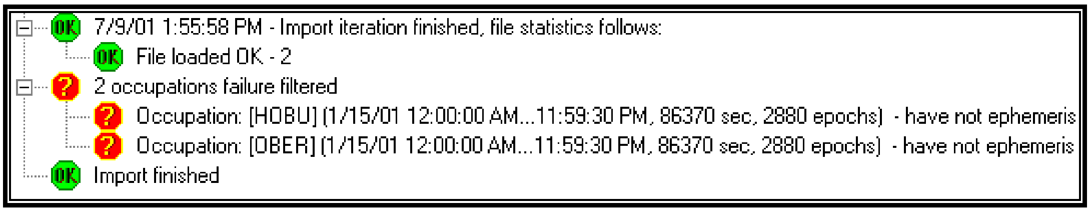


Figure 7-2

Imported but not filtered occupations will be put into the session '***_Import'*** as shown in Figure 7-3:

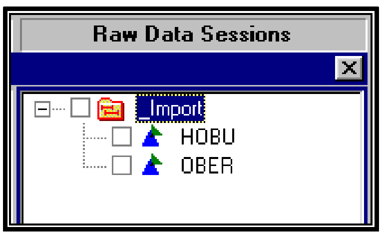


Figure 7-3

Note that the icon is used for the ‘***_Import’*** session[4].
The user will not be able to drag-and-drop such a session into a solution for further processing.
When loading ‘additional’ ephemeris data (broadcast, precise or both orbit types) for an imported yet unfiltered occupation, the submodule *RawFilter* will run, and the user will see the following information in the *Import* window:

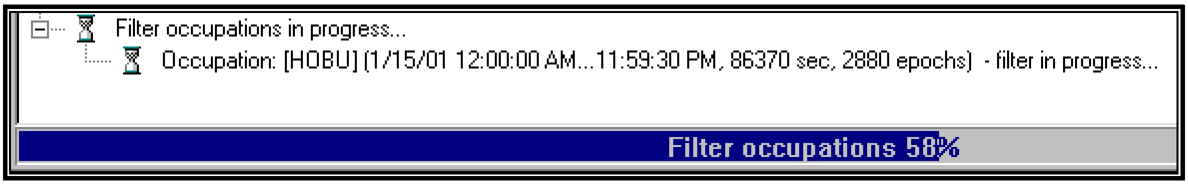


Figure 7-4

Once the occupation filtration is finished, the repaired occupations will be placed in normal sessions so that the user can then drag-and-drop these sessions into a desired solution.

4) ‘Normal’ sessions will be marked with .

8. *Import Setup*

Press the button  (*Setup*) to open the *Import setup* dialog window:

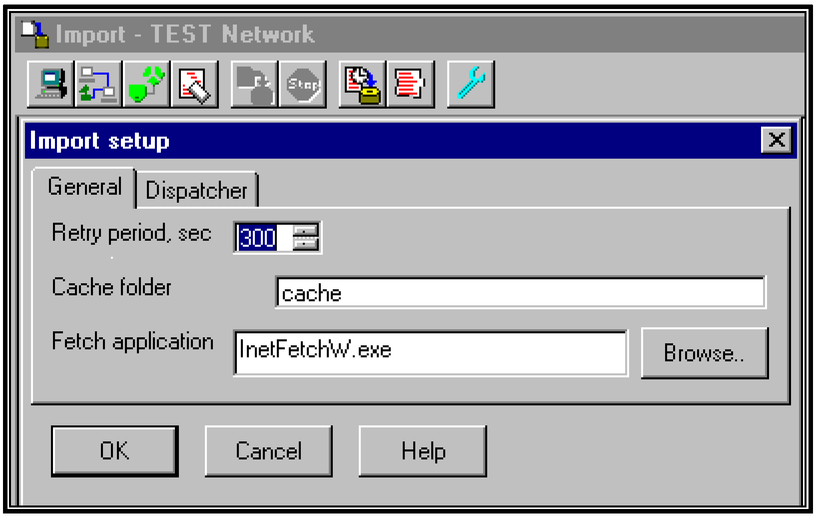


Figure 8-1

Here the user can specify a *retry period* other than the default one (5 minutes).
If a scheduled channel cannot be activated at that moment (i.e. because the specified local file is not found, or the server is temporarily down, or the receiver is not connected to the port properly, etc.), *Import* will re-try data downloading periodically[5].

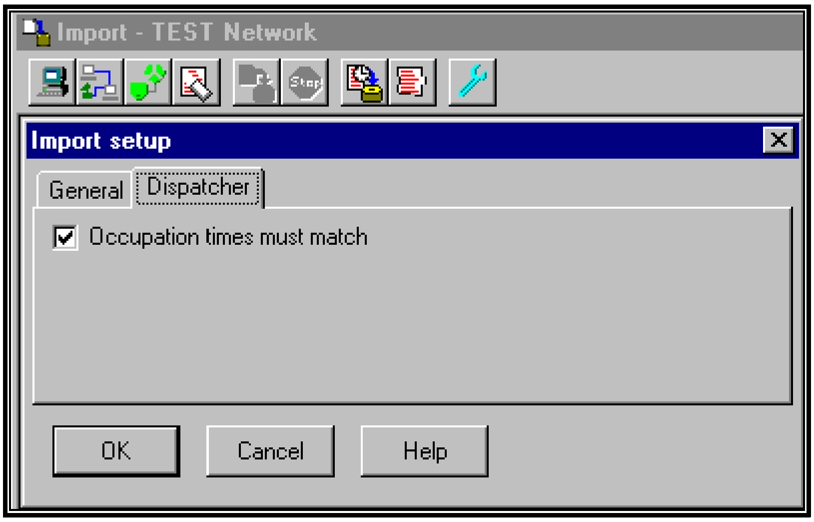


Figure 8-2

This checkmark means that a planned occupation will be replaced with a newly imported one if and only if they overlap in time (setting aside other requirements).

[5]) Assuming that *import* is activated with the *Make* command

Pinnacle™
Reference Documentation
Suite

Control Data Lists

User's Manual

This documentation reflects
the April 4, 2001 version
of Pinnacle 1.0

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1 Introduction to Control Data Lists

Control Data Lists (or CDLs for brevity) contain the coordinates of control points used for ***processing*** and ***adjustment***. CDLs can be accessed either from the project root (see *Figure 1-1*) or through individual networks (see *Figure 1-2*). Control data lists located in the project root are accessible from all networks existing in the given project. Control data assigned to a specific network are accessible only from this network.

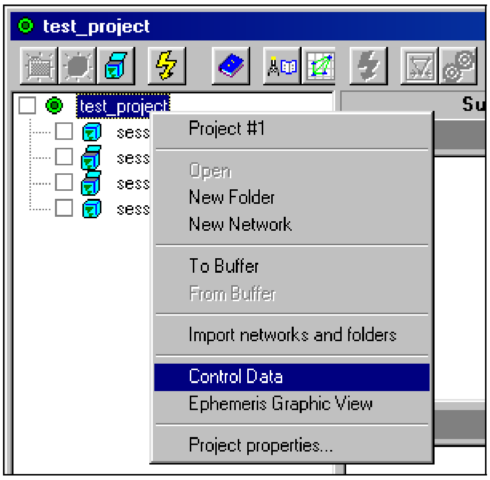


Figure 1-1

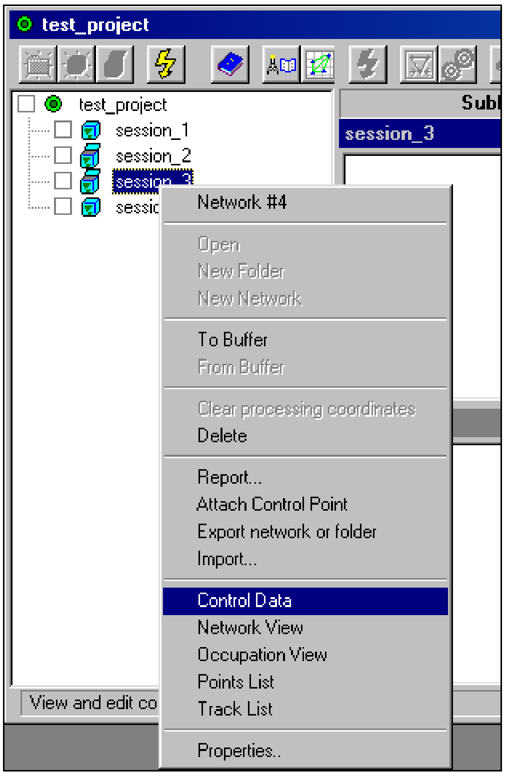


Figure 1-2

Any number of CDLs can be created for a project or a network.

CDLs contain the coordinates, names, rms errors and some other attributes/properties of control points. Given a control point, you may assign to it one or more *control data items* determining the point's coordinates in the selected coordinate system (geodetic, Cartesian, plane) and datum.

2 Creating and Editing Control Data Lists

CDLs for a project or a network can be created

- manually
- by importing data from different external file formats, or
- by exporting data from a subnet.

You can create your CDLs with or without the Control Data Wizard.

2.1 Manual mode with using the Wizard

To create or edit CDLs for a project or a network, right-click on the corresponding project's or network's node in the project tree and choose '*Control Data*' from the pop-up menu (see ***Figure 2-1***).

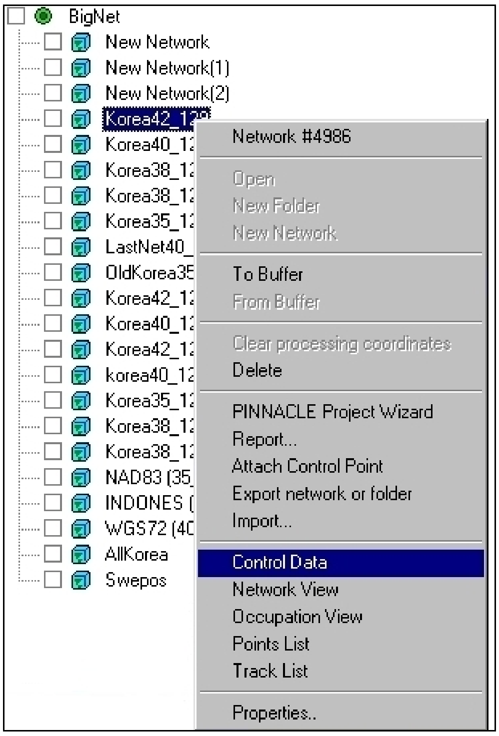


Figure 2-1

The two-panel *Control Data* window will be opened as shown in ***Figure 2-2:***

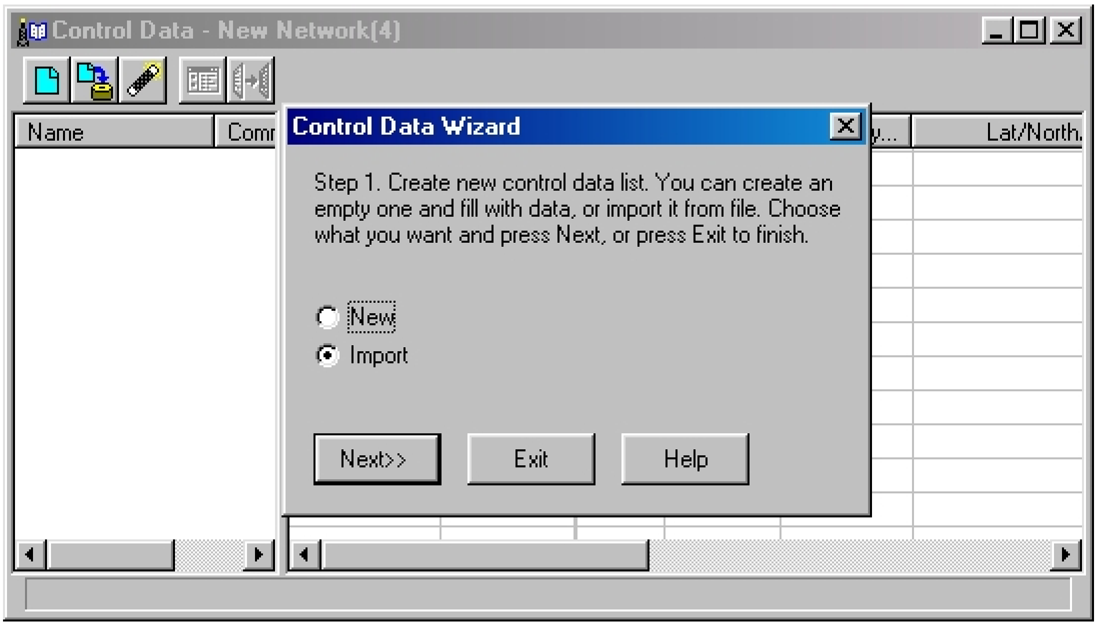


Figure 2-2

In the left-hand panel you will see the CDLs available in the selected project or network. Note that for a newly created project or network the left-hand panel will be empty. The right-hand panel will display the *control point Items* relating to the selected CDL.

Once the '*Control Data*' option is chosen, the 'Control Data Wizard' will pop up (see ***Figure 2-2***). Note that if the wizard is currently disabled you can return itwith the toolbar's button at the top of the 'Control Data' window or by running the 'Control Data Wizard' command from the corresponding menu (to open this menu, right-click somewhere in a blank area of the left-hand panel).

A new Control Data list will be created step by step.

Figure 2-3

In ***Step 1***, the Control Data Wizard prompts you to specify the way in which the control data list will be generated:

- by creating a new control data list in 'semi-automatic' mode or
- by importing control data from a file.

Depending on your specific task, press the '*New*' radio button to create a new control data list manually, or select '*Import*' to import control data from a file.

To proceed to the next window, press the '*Next*' button. If you wish to disable the Wizard and create a new control data list yourself, press '*Exit*'.

See sections 2.3 and 2.4 about how import CDLs from external files.

If you choose to remain with the Wizard and select 'New' to create a new control data list, the '*Properties for Control Data List*' dialog box will appear. This dialog box has only one tab, '*General*' (see ***Figure 2-4***). In this tab you must enter a CDL name (otherwise the 'OK' button will remain grayed out). In the '*Comment*' field, you can enter additional information about the newly created control data list, if necessary.

Figure 2-4

Press '*OK*' to proceed to **Step 2**, which allows for the creation of new *control data items* for selected points. First you will need to select the desired coordinate type: Grid, Geodetic or Cartesian coordinates (see ***Figure 2-5***).

Figure 2-5

Press the '*Next'* button to proceed with creating a new control data item. Otherwise, press the '*Exit'* button to quit the procedure.

After 'Grid' has been chosen, you will need to set up the parameters required for the '*General*' tab of the '*Properties for item of control point*' dialog window as shown in ***Figure 2-6***) .

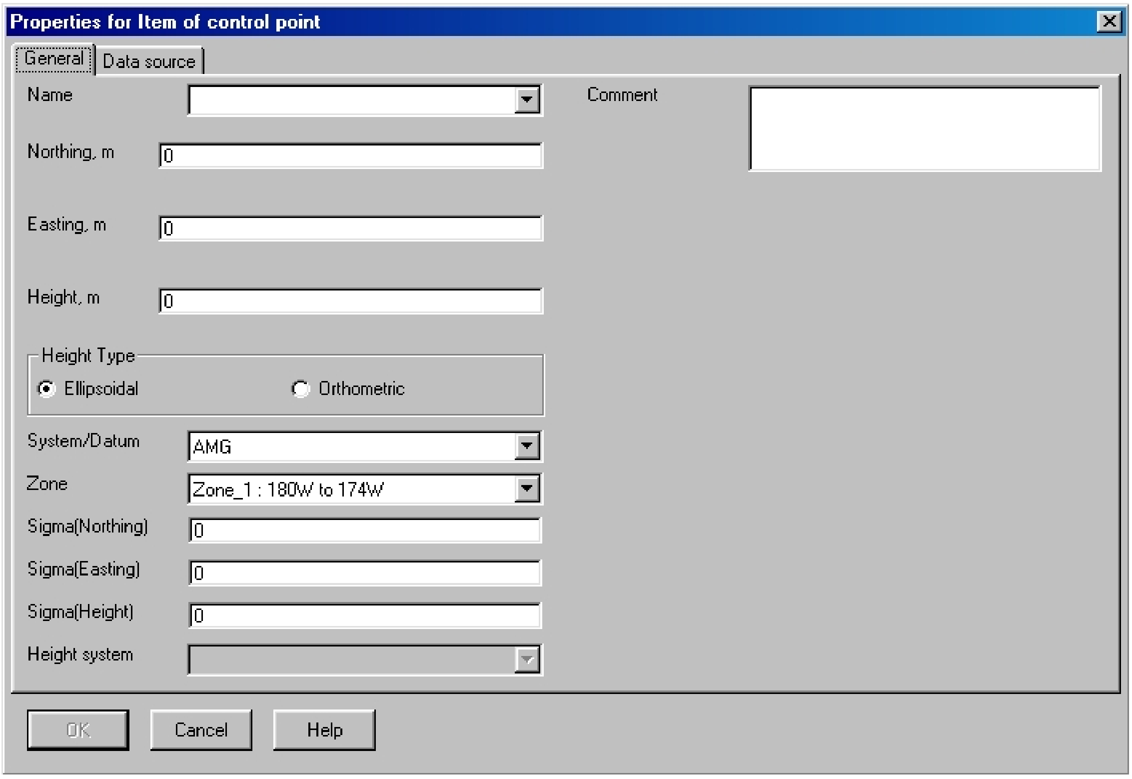


Figure 2-6

First enter the name of the control data item in the '*Name*' field.

The '*Northing*', '*Easting'* and '*Height'* edit boxes are, as their names imply, intended to enter the plane coordinates and the height.

The '*Height type*' radio button group allows you to choose between *ellipsoidal* and *orthometric* height.

From the '*System/Datum'* listbox, you will select the coordinate system in which the entered coordinates are specified.

The '*Zone'* listbox will indicate the projection zone. The projection type and projection zone length will depend on the coordinate system selected.

With the '*Sigma(Northing)'*, '*Sigma(Easting)'* and '*Sigma(Height)'* edit boxes you will specify the rms errors for the entered grid coordinates.

When working with orthometric heights, press the 'orthometric' radio button and then select the desired '*Height system*'. **[This feature is not implemented in the current version of Pinnacle]**.

In the '*Comment'* field you can enter additional information if necessary.

The '*Data source'* tab of the '*Properties for Control Data List'* dialog window will display information about the file from which the *control data* have been imported.

If you have selected '*Geodetic'* to create a new control data item, you will then need to set up the '*General*' tab as shown in ***Figure 2-7***:

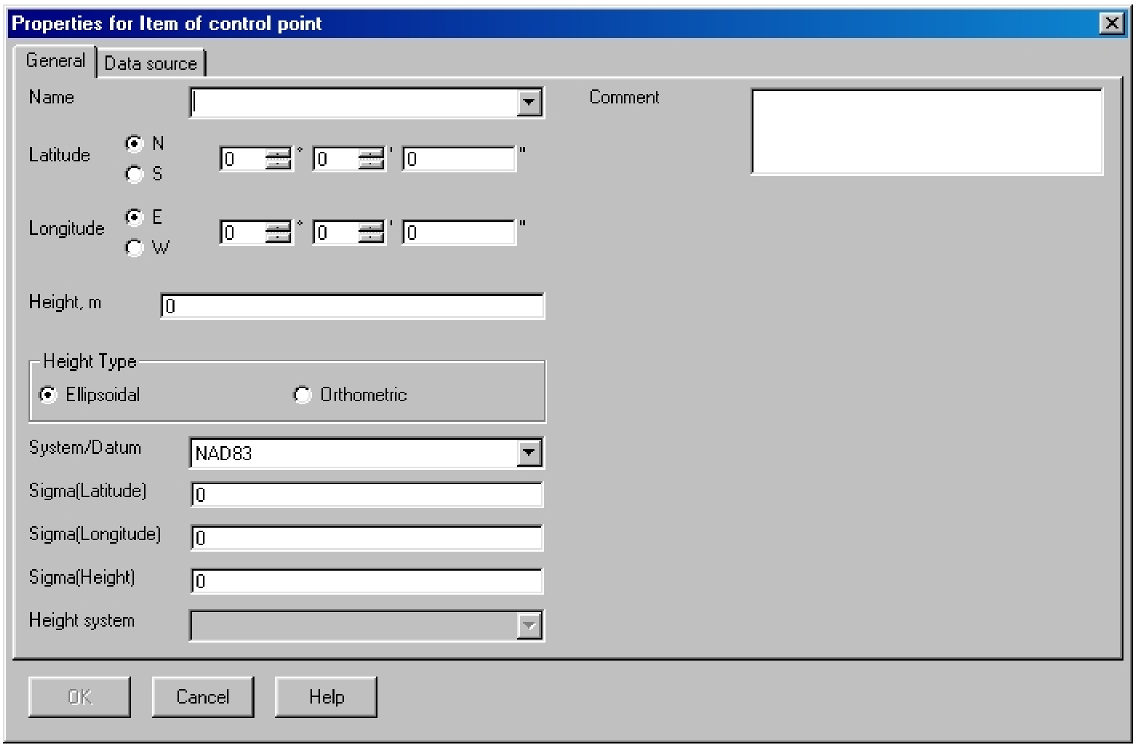


Figure 2-7

First enter the name of the control data item created.

Then enter the geodetic coordinates *Latitude*, *Longitude*, and *Height*.

Use the '*Height type'* radio buttons to choose between ellipsoidal and orthometric height.

From the '*System/Datum*' listbox select the coordinate system that the given geodetic coordinates refer to.

Use the editboxes '*Sigma(Latitude)'*, '*Sigma(Longitude*)' and '*Sigma(Height)'* to enter the rms errors for the corresponding coordinates.

If '*Orthometric'* has been chosen, select the desired height system from the '*Height system'* listbox. **[This is not implemented in the current version of Pinnacle].**

In the '*Comment*' field enter additional information, if required.

The other tab, '*Data source*', will show what file the control data have been imported from.

If '*Cartesian'* has been selected to create a new control data item, you will set up the following dialog box (see ***Figure 2-8***).

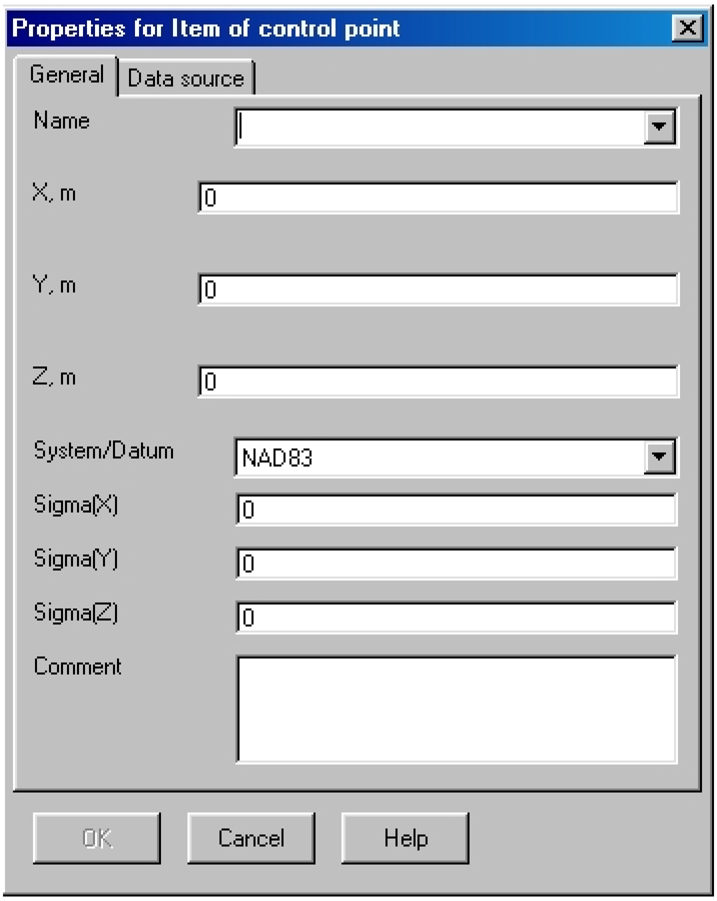


Figure 2-8

First, enter the name of the control data item and its Cartesian coordinates X, Y, Z.

From the '*System/Datum*' listbox, select the coordinate system that the specified cartesian coordinates refer to.

In the editboxes '*Sigma(X)', 'Sigma(Y)'* and '*Sigma(Z)'* enter the rms errors (in meters) of the specified coordinates.

In the '*Comment*' field you can enter any additional information if required.

The '*Data source*' tab will show what file the control data have been imported from.

After setting the 'Properties for item of control point' dialog window, press '*OK*' to proceed to the next dialog box. The Wizard will prompt you to create another Control Data List or Control Data Item for the current control data list.

Choose the option you need and proceed with creating control data with or without the Wizard (by pressing '*Next'* or '*Exit'* respectively).

Figure 2-9

Once a CDL is created (and highlighted), you will see in the right-hand panel the Control Data Items together with their attributes, specifically:

Coordinate System — Zone (relevant only for Grid System) — Height Type — Height system — Lat/North/X — Lon/East/Y — Height/Height/Z — Sigma:Lat/North/X — Sigma:Lat/East/Y — Sigma:Height/Z — Data source.

2.2 Manual mode without using the Wizard

If you do not want to use the Wizard while creating a new control data list, right-click on the corresponding node in the project tree and choose '*Control Data*' from the pop-up menu to display the *'Control Data'* window.

To create a new control data list, you will either press the button  on the '*Control Data*' window's toolbar or, alternatively, right-click somewhere in an empty area in the window's left-hand panel and choose the '*New Control Data List'* option from the pop-up menu:

Figure 2-10

In the '*General*' tab of the '*Properties for Control Data List*' window, you will need to enter the item name. In the '*Comment*' editbox you can type any additional information if necessary (see ***Figure 2-11***).

Figure 2-11

Once you press the '*OK*' button, the name of the newly created control data list will appear in the left-hand panel (see ***Figure 2-12***). Note that no control points have been specified as yet.

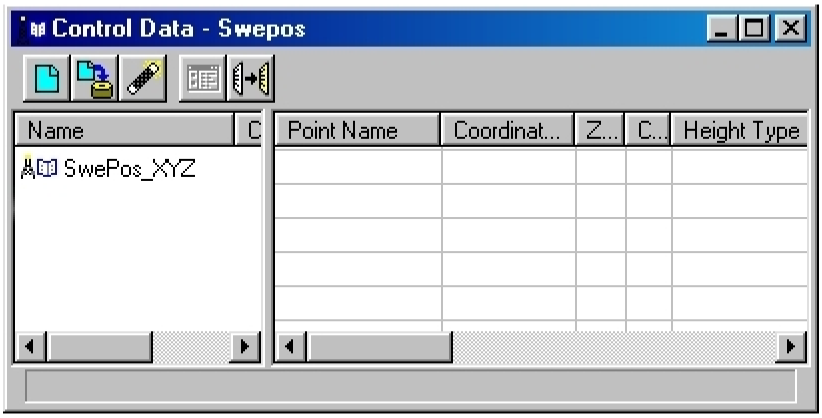


Figure 2-12

Note that CDLs and Control Data Items are *Pinnacle objects* and therefore they have context menus associated with them. Throughout Pinnacle, such menus can be opened by right-clicking on the corresponding objects.

Right-click the name of the newly created list, choose the '*New Item'* option from the pop-up menu and then choose the desired coordinate type (see ***Figure 2-14***).

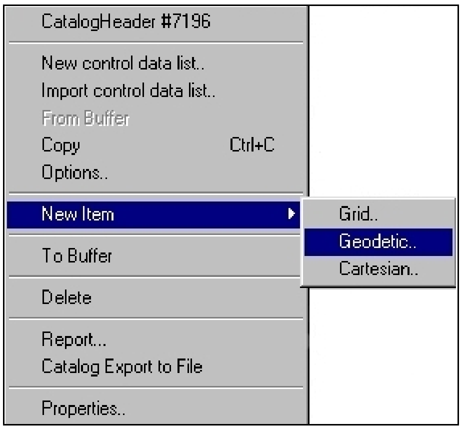


Figure 2-13

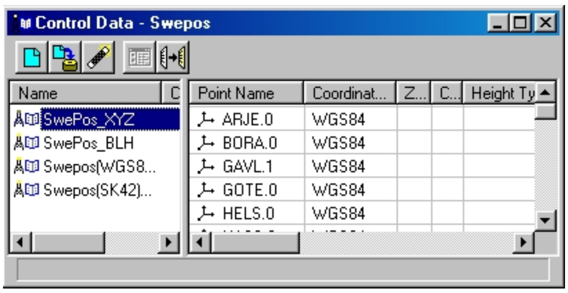


Figure 2-14

Your further actions will be the same as described in section 2.1 for ***Step 2***.
To add a new item to a CDL, right-click on the control data list name in the '*Control Data*' window's left-hand panel. A menu will pop up. Select the '*New Item*' option and then specify the desired coordinate type as shown in ***Figure 2-14***.
If you need to edit the properties of an item in a CDL, right-click on the corresponding item in the right-hand panel of the '*Control Data*' window.

Note that if you have any problem with handling the control data on your own,invoke the Control Data Wizard by pressing the toolbar's button .

2.3 Import of Control Data

This operation can be performed in one of the following three ways:

- **With the Wizard**

  If you want to import control data from an external file (while remaining with the Wizard), select the 'Import' option as shown in ***Figure 2-16*** and press '*Next*':

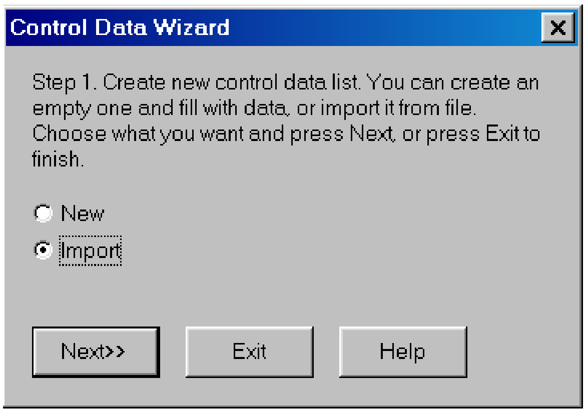


Figure 2-15

  Press '*Next'* to open the standard '*File|Open'* dialog box.

- **Without the Wizard by using the pop-up context menu**

  If you prefer to import control data files without using the Wizard, right-click somewhere in a blank area of the '*Control Data*' window's left-hand panel and choose the '*Import Control Data List*' option from the pop-up menu (see ***Figure 2-17***).

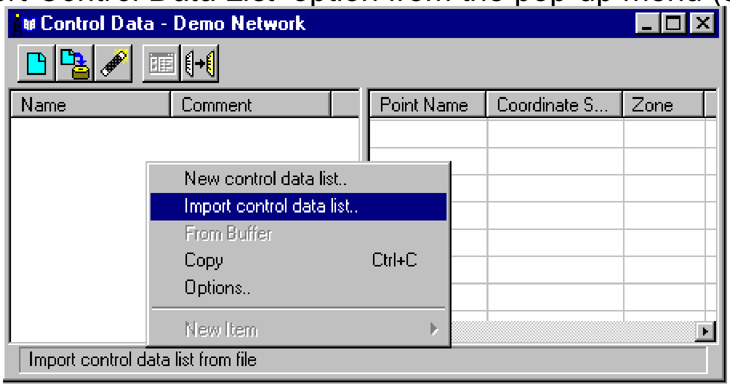


Figure 2-16

After this, the standard '*File|Open'* dialog box will be opened.

- **Without the Wizard by using the toolbar's button**

  In this case, you will press the toolbar's button to open the '*File|Open'* dialog box.

Once the standard '*File|Open*' dialog window is opened (see ***Figure 2-18***), you must select the desired import file.

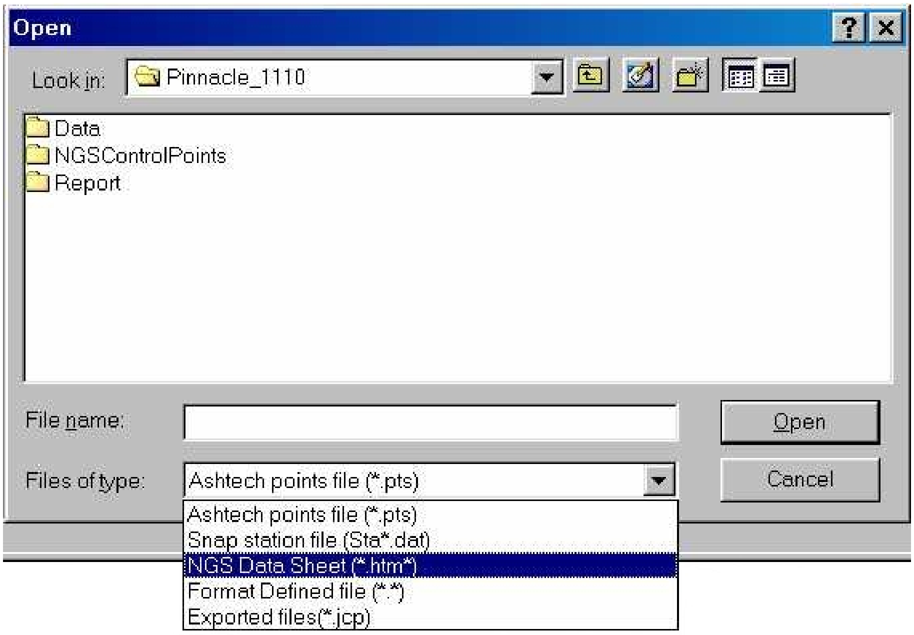


Figure 2-17

Pinnacle allows the import of the following control data file formats:

- NGS Datasheets (*.htm or *.dat)
- Ashtech points files (*.pts)
- SNAP station files (Sta*.dat)
- Pinnacle exported <u>J</u>PS <u>C</u>ontrol <u>P</u>oints files (*.jcp)
- User-defined format files (*.*).

Having imported all necessary control data, you will see a resulting '*Control Data*' window similar to the example shown in *Figure 2-19*. Note that the right-hand panel will display the control points corresponding to the highlighted CDL.

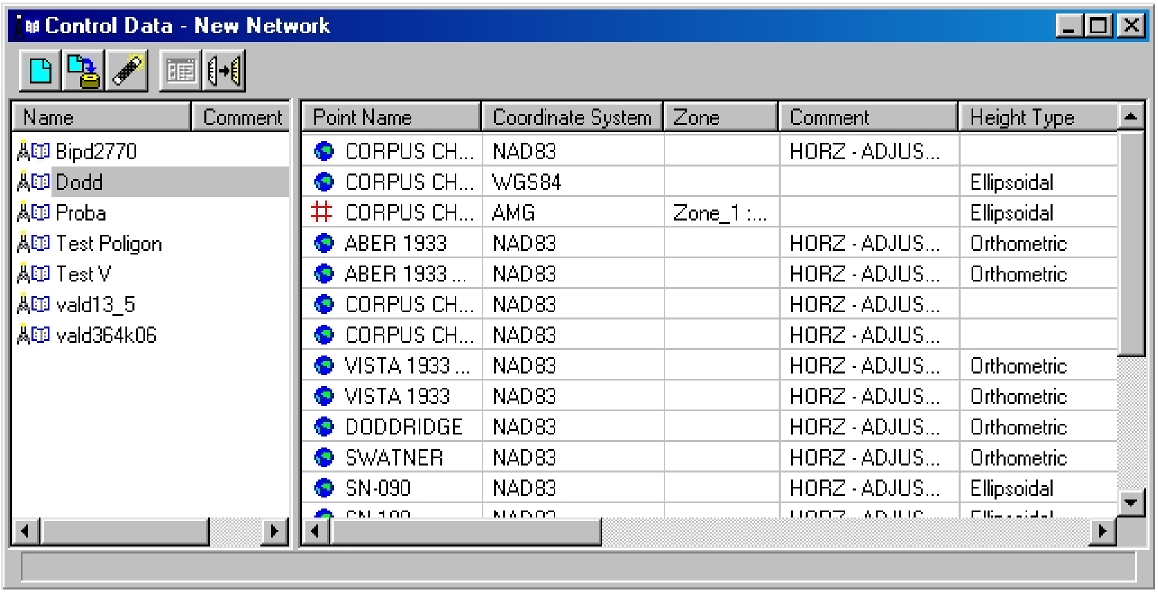


Figure 2-18

2.4 Import of Control Data from User-Defined Formats

Beside the standard file formats such as Ashtech points files, Snap station files and NGS data sheets, Pinnacle also supports user-defined text file formats. To import a user-defined ASCII file format, choose the template Format Defined File (*.*) from the filename template list and then open the desired control data file. Below is an example of the control data file opened in this way:

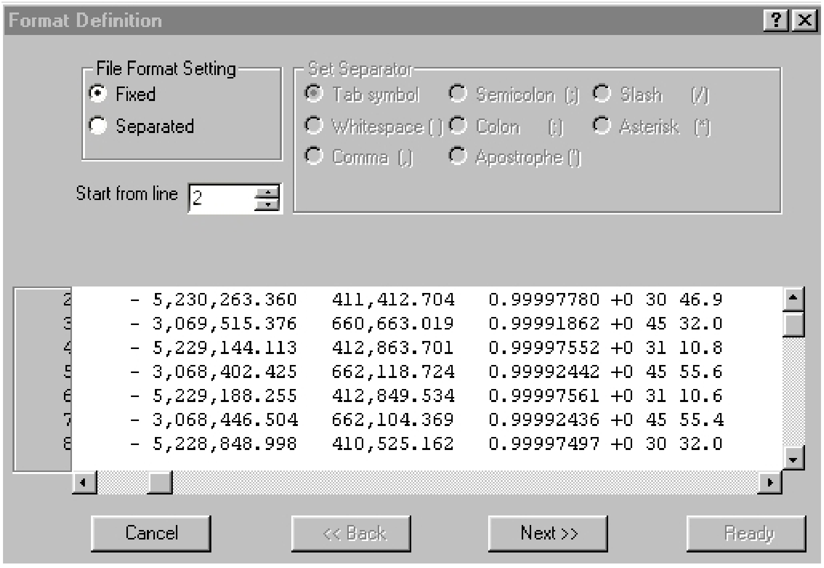


Figure 2-19

Note that a user-defined ASCII control data file must look like a flat table, i.e. the following requirements must be met:

- one line per point
- either fixed-width columns are used to separate individual numbers in rows (see ***Figure 2-21***):

Figure 2-20

- or, delimiters are used for this purpose (see ***Figure 2-22***):

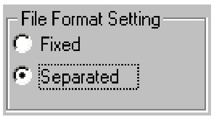


Figure 2-21

The following symbols can be used as delimiters (see ***Figure 2-23***):
tab symbol, white space, comma, semicolon, colon, apostrophe, slash, and asterisk.

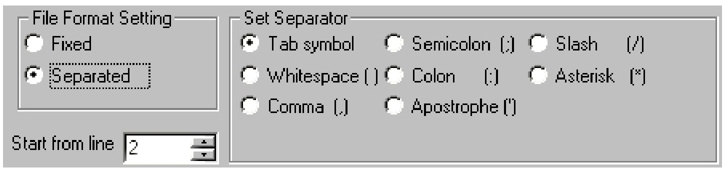


Figure 2-22

The user will first press the '*Separate'* radio button and then choose the correct delimiter type from the '*Set Separator*' group.

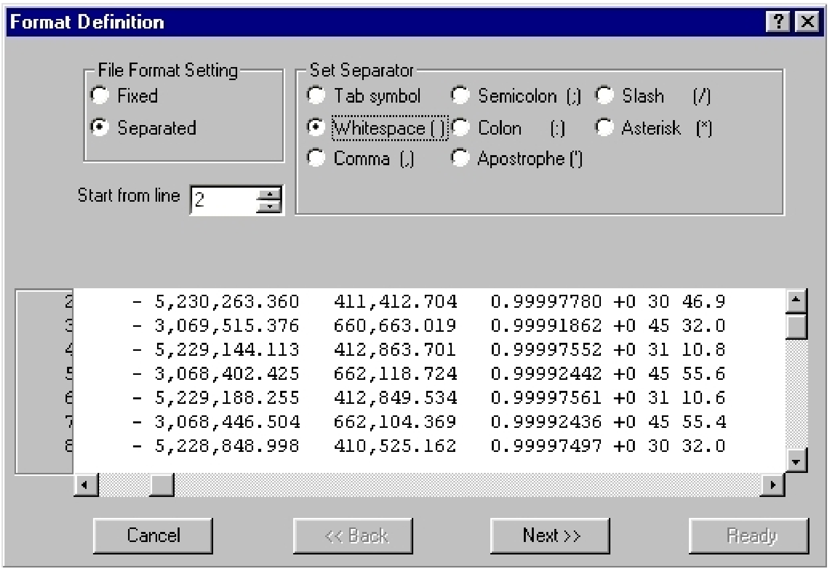


Figure 2-23

The '*Start from line…*' spinbox is used to specify the starting line for Pinnacle to import the file's contents. After the delimiter type is selected, press the '*Next*' button.

In the '*Set System Type*' radio button group, select the desired coordinate type: '*Cartesian*', '*Geodetic*' or '*Grid*' (see ***Figure 2-25***, ***Figure 2-26***, ***Figure 2-27***, respectively).

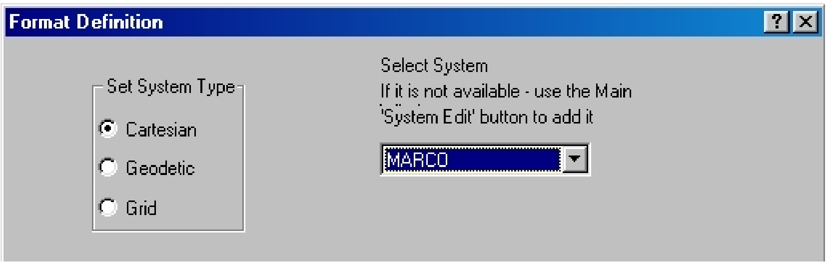


Figure 2-24

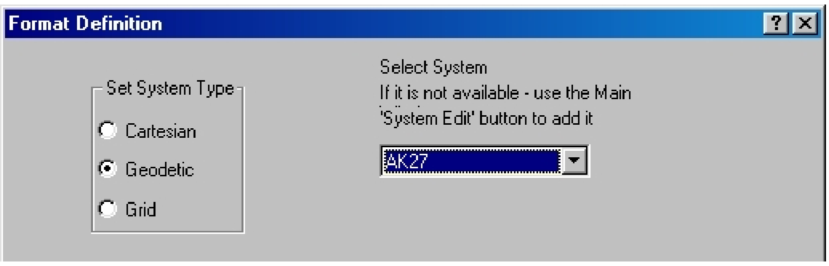


Figure 2-25

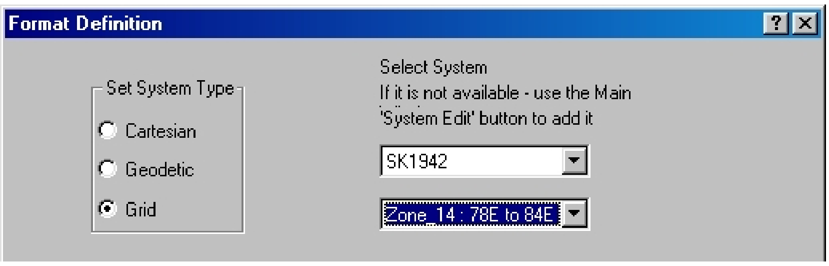


Figure 2-26

If you have chosen either '*Cartesian*' or '*Geodetic*', then use the '*Select System*' listbox to select the desired coordinate system.

If you have chosen '*Grid'*, specify both the coordinate system and projection zone. Press the '*Next'* button to continue.

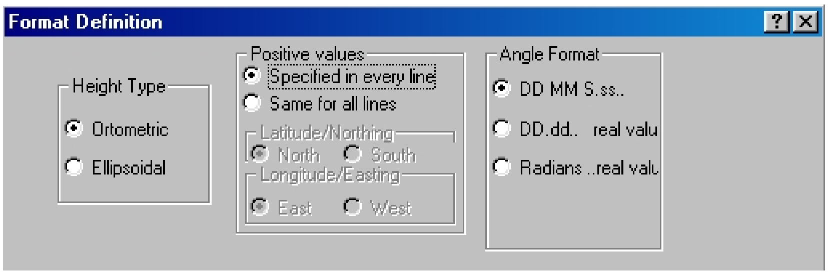


Figure 2-27

If you have specified '*Geodetic'* or '*Grid'*, select between the '*Orthometric'* and '*Ellipsoidal'* height type by using the '*Height Type'* radio button group:

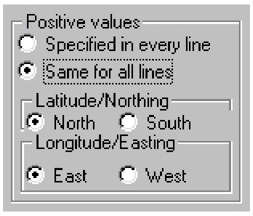


Figure 2-28

With the '*Positive values*' radio buttons you will govern the way Pinnacle interpretsthe sign of the geodetic/grid coordinates.

Latitudes that are given without the sense mark in the import file will be interpreted as *northern latitudes.* Similarly, longitudes that are given without the sense mark will be interpreted as *eastern longitudes.*

Case#1: '*Specified in every line*' is selected. In this case, signs used in different rows will be considered independent from each other. All coordinates will be interpreted according to their senses[1], which may be specified implicitly or explicitly. No 'on-the-move' sign inversion will be carried out while importing the control data.

Case#2: '*Save for all lines*' is selected. Consider in detail how Pinnacle will interpret latitudes/longitudes and northing/easting in control data files depending on which buttons are selected in the '*Latitude/Northing*' and '*Longitude/Easting*' radio button groups.

- If the button '*North*' is pressed, the latitudes and *northing*-coordinates will maintain their original signs.
- If the button '*South*' is pressed, the signs of the latitudes and *northing*-coordinates will be inverted while importing the file.
- If the button '*East*' is pressed, the longitudes and *easting*-coordinates will maintain their original signs.
- If the button '*West*' is pressed, the signs of the longitudes and *easting*-coordinates will be inverted while importing the file.

[1]) these are N/S for latitude and E/W for longitude

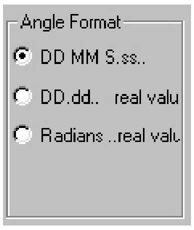


Figure 2-29

In the '*Angle Format*' radio button group, select the correct angle presentation format.

Press the '*Next'* button to display the dialog window with the control data that you are going to import (see ***Figure 2-30***).

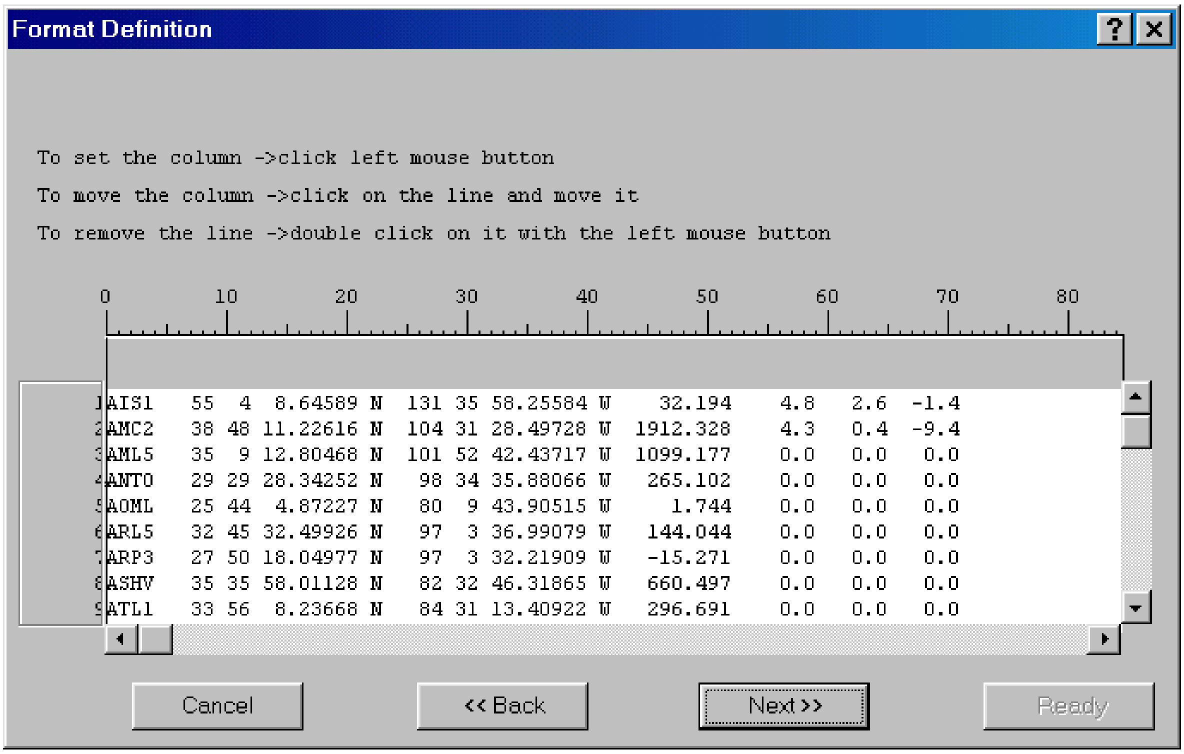


Figure 2-30

This dialog box must be formatted with the vertical lines to delimit individual columns from each other. To insert a vertical line for a column, place the cursor next to this column somewhere in the scale ruler area and then click the left mouse button (note the line *"to set the column -> click left mouse button"* in *Figure 2-30*).

It is possible to drag-and-drop vertical lines with the mouse if necessary. To move a vertical line, place the cursor on the line and press the left mouse button. The vertical line will become ***red***. Drag the line to a new position while holding down the LMB (note the line *"to move the column -> click on the line and move it"* in *Figure 2-30*).

Also, it is possible to remove a line by double clicking on it (note the prompt "*to remove the line -> double click on it with left mouse button*" in *Figure 2-30*).

Once youhave finished with formatting the columns, press the '*Next'* button to continue.

Depending on the earlier specified coordinate type, one of the three following dialog windows will appear.

For Cartesian coordinates:

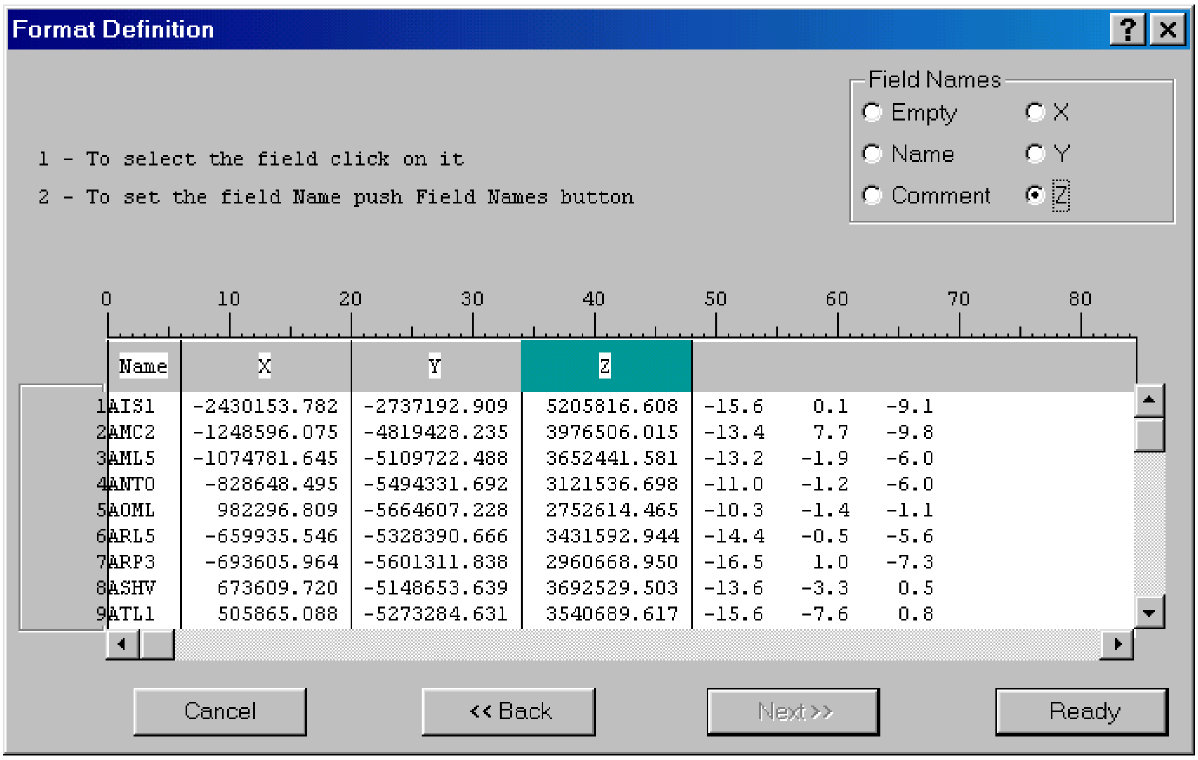


Figure 2-31

For Geodetic coordinates:

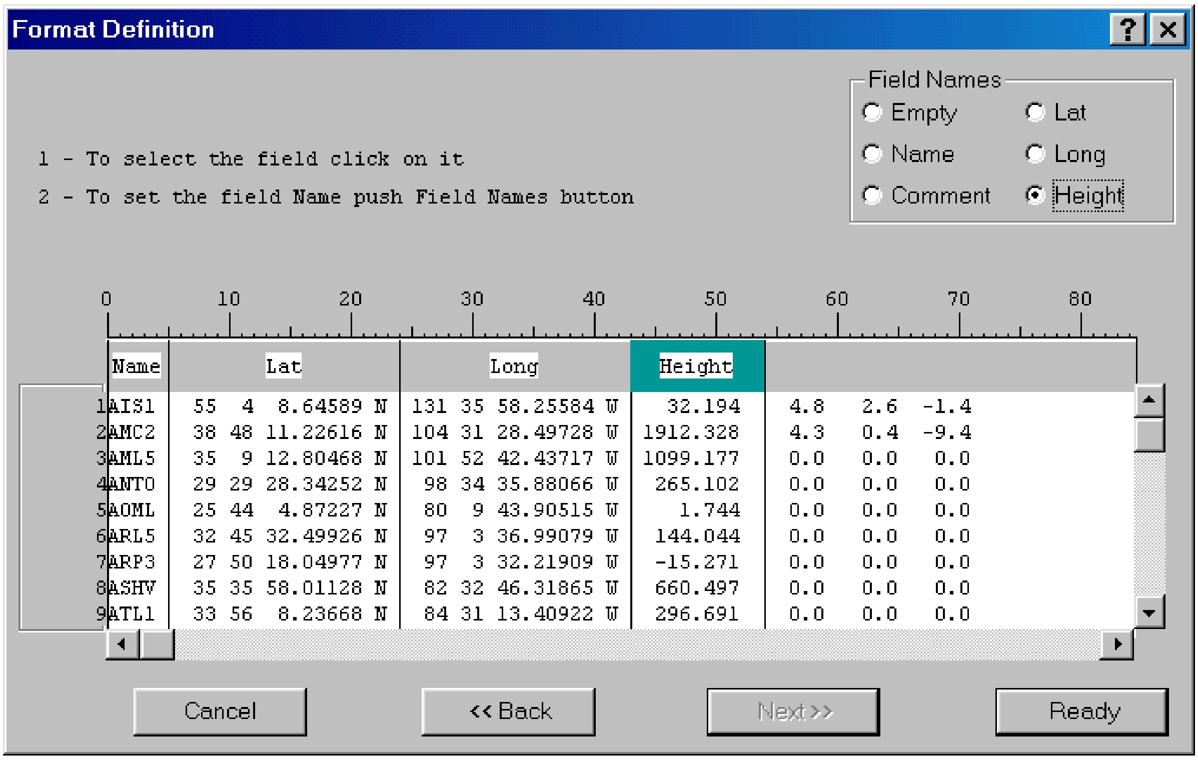


Figure 2-32

For Grid coordinates:

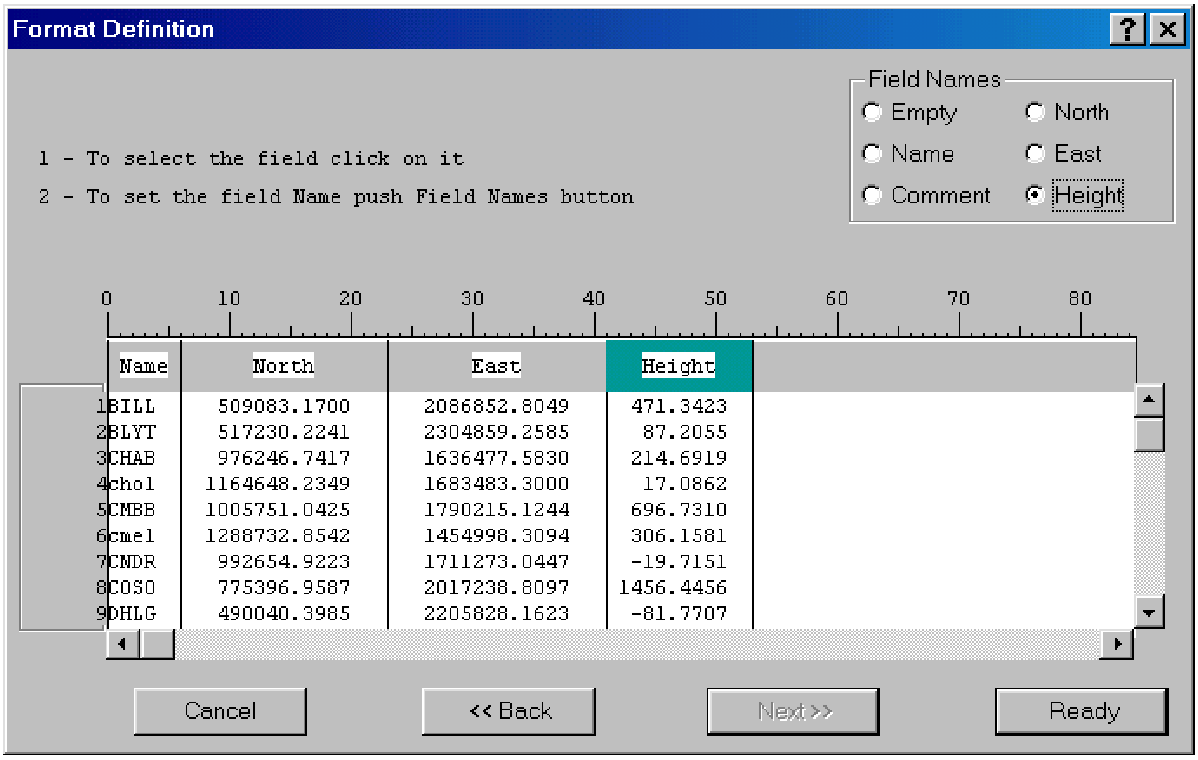


Figure 2-33

Now, it is necessary to assign each column its name by using the '*Field Names*' radio button group. To do this, place the cursor in the scale ruler area above the corresponding column. This area will become green (as shown for the '*Height'* column in ***Figure 2-33***). Finally press the desired radio button to assign the column the correct name.

Press the '*Ready'* button to complete the import of the file.

Next, describe how to handle import files based on delimiters, not fixed-width columns (see the example in ***Figure 2-34***)

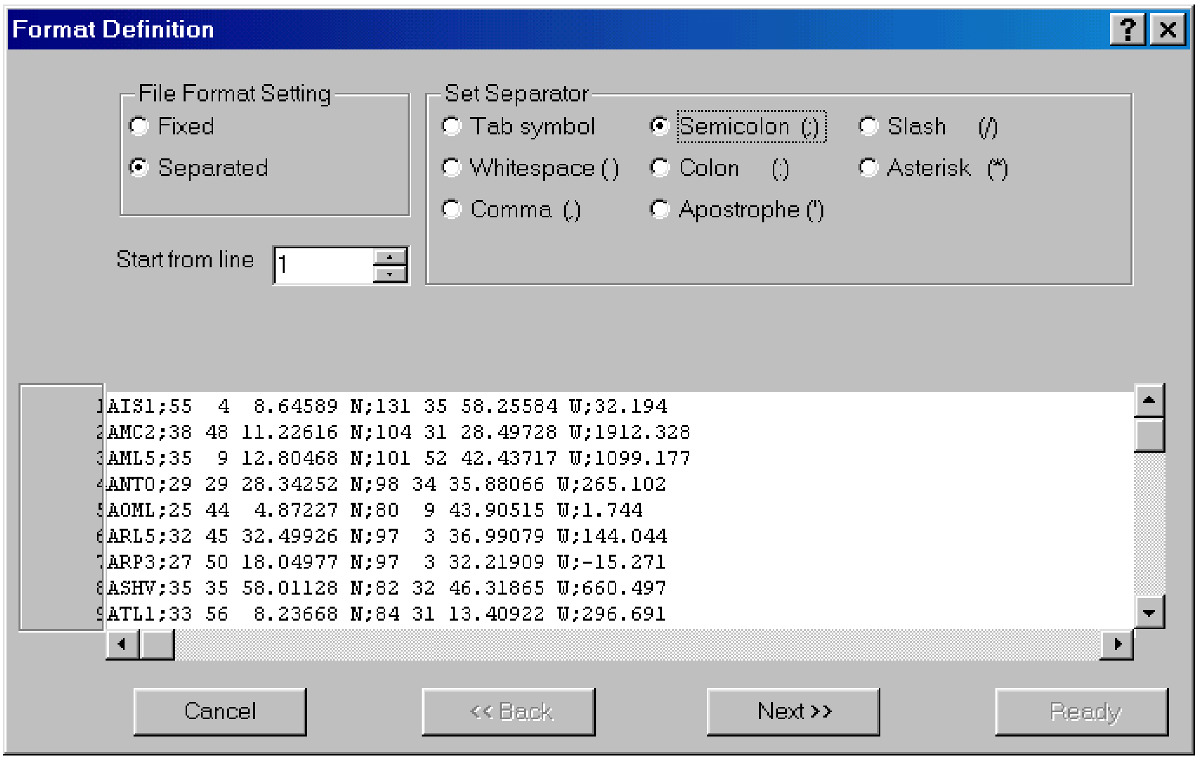


Figure 2-34

In this example, it is semicolons that are used as delimiters.

Press the '*Next*' button to proceed to the following dialog window.

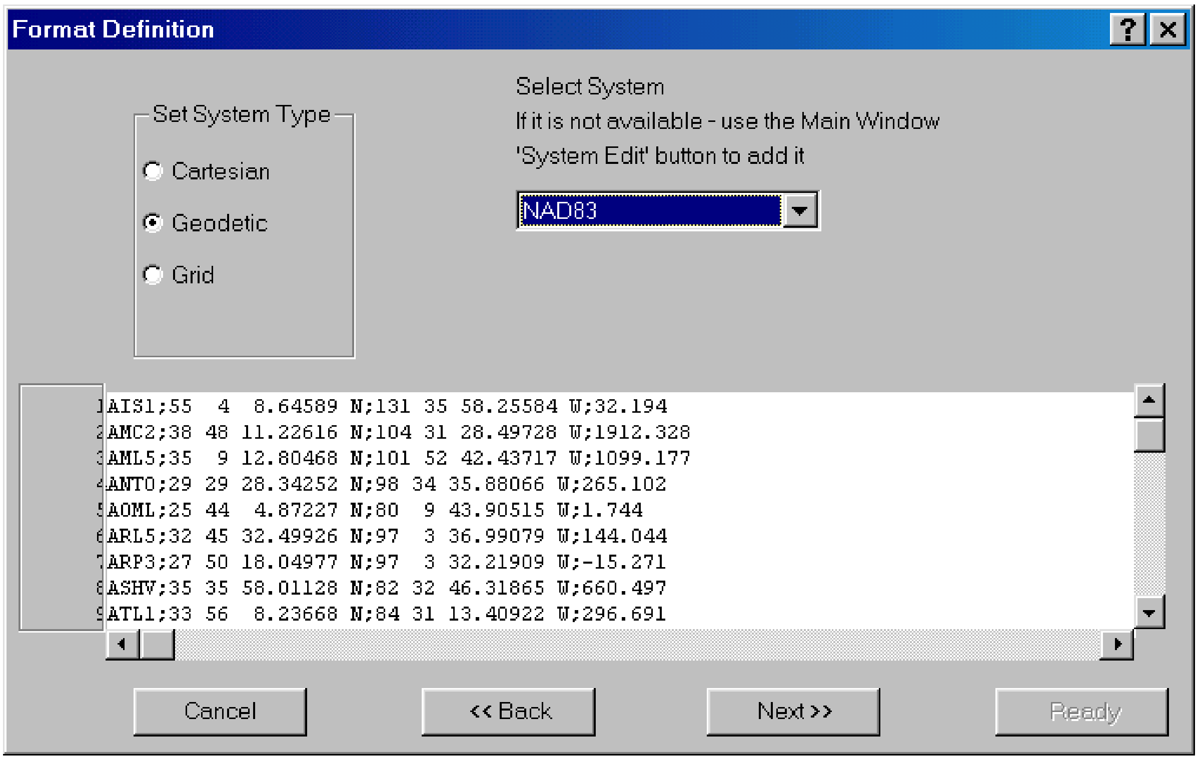


Figure 2-35

In the example shown in ***Figure 2-35***, geodetic coordinates are used (see the '*Set System Type*' radio button group). In this dialog window the user will select the coordinate system and, if necessary, specific projection zone. Press the '*Next'* button to continue.

In the next window the user can visually check the correctness of data formatting and assign columns their names with the help of the '*Field Names'* radio button group (see ***Figure 2-36***).

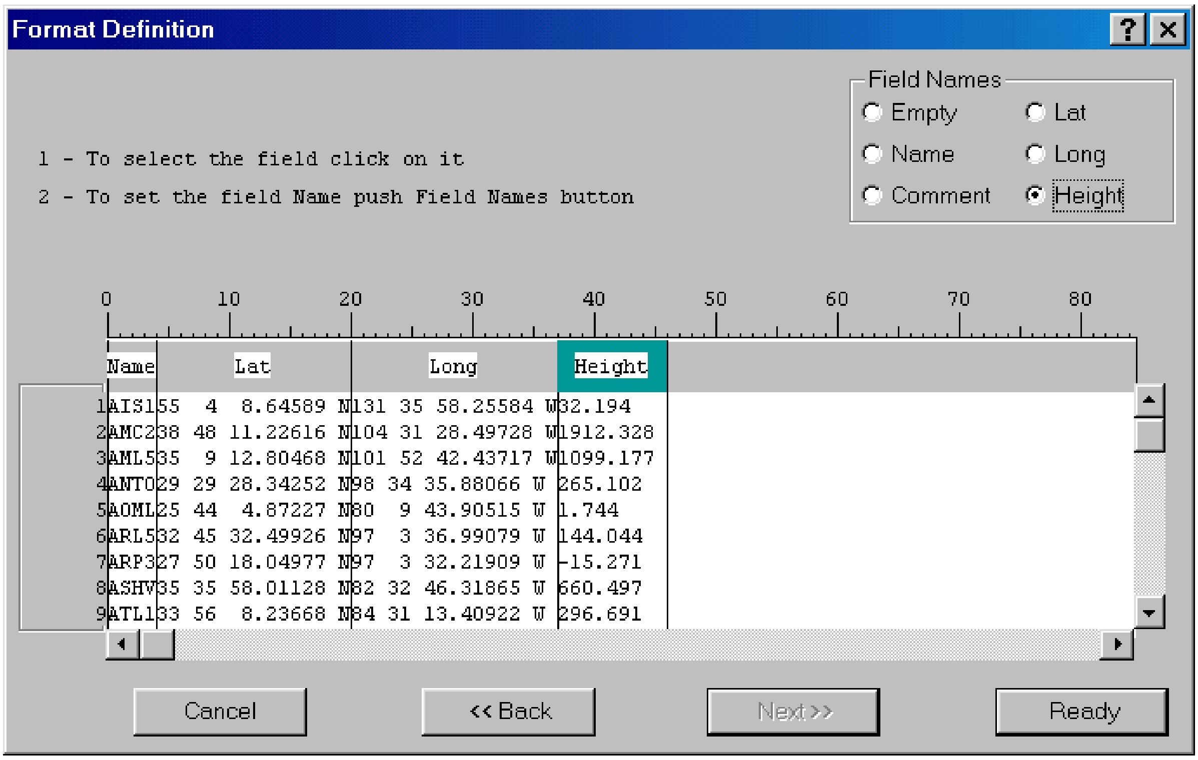
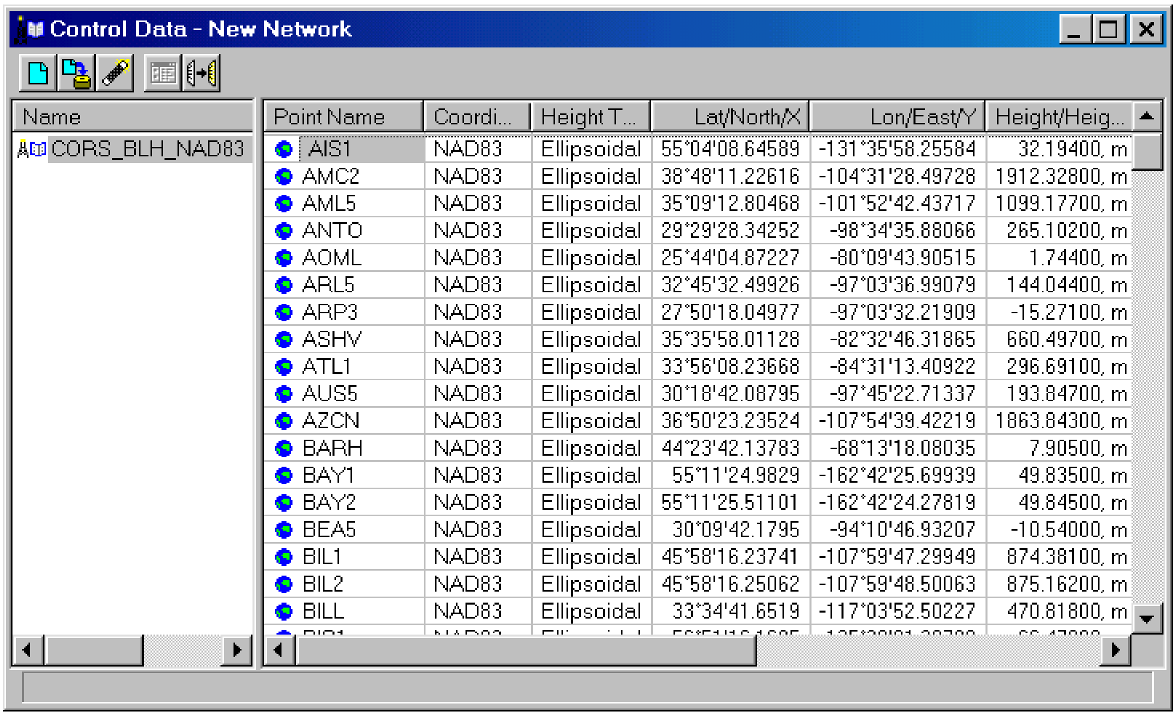


Figure 2-36

Press the '*Ready*' button to complete the file import.

Note that only named columns are subject to import (i.e. all unnamed columns will be ignored while importing the file). Also note that the linefeed /carriage return symbols are used to distinguish control data specified for different points.

Finally, a new CDL will appear in the 'Control Data' window as shown in ***Figure 2-37***:


Control Data - New Network

Name: CORS_BLH_NAD83

Point Name	Coordi...	Height T...	Lat/North/X	Lon/East/Y	Height/Heig...
AIS1	NAD83	Ellipsoidal	55°04'08.64589	-131°35'58.25584	32.19400, m
AMC2	NAD83	Ellipsoidal	38°48'11.22616	-104°31'28.49728	1912.32800, m
AML5	NAD83	Ellipsoidal	35°09'12.80468	-101°52'42.43717	1099.17700, m
ANTO	NAD83	Ellipsoidal	29°29'28.34252	-98°34'35.88066	265.10200, m
AOML	NAD83	Ellipsoidal	25°44'04.87227	-80°09'43.90515	1.74400, m
ARL5	NAD83	Ellipsoidal	32°45'32.49926	-97°03'36.99079	144.04400, m
ARP3	NAD83	Ellipsoidal	27°50'18.04977	-97°03'32.21909	-15.27100, m
ASHV	NAD83	Ellipsoidal	35°35'58.01128	-82°32'46.31865	660.49700, m
ATL1	NAD83	Ellipsoidal	33°56'08.23668	-84°31'13.40922	296.69100, m
AUS5	NAD83	Ellipsoidal	30°18'42.08795	-97°45'22.71337	193.84700, m
AZCN	NAD83	Ellipsoidal	36°50'23.23524	-107°54'39.42219	1863.84300, m
BARH	NAD83	Ellipsoidal	44°23'42.13783	-68°13'18.08035	7.90500, m
BAY1	NAD83	Ellipsoidal	55°11'24.9829	-162°42'25.69939	49.83500, m
BAY2	NAD83	Ellipsoidal	55°11'25.51101	-162°42'24.27819	49.84500, m
BEA5	NAD83	Ellipsoidal	30°09'42.1795	-94°10'46.93207	-10.54000, m
BIL1	NAD83	Ellipsoidal	45°58'16.23741	-107°59'47.29949	874.38100, m
BIL2	NAD83	Ellipsoidal	45°58'16.25062	-107°59'48.50063	875.16200, m
BILL	NAD83	Ellipsoidal	33°34'41.6519	-117°03'52.50227	470.81800, m

Figure 2-37

2.5 Exporting An Adjusted SubNet's Points as Control Data

After the constrained adjustment of a subnet is complete, the user can export the points' adjusted coordinates to a new CDL[2].

To do this, right-click on the desired subnet node and select the '*SubNet to Control Points*' option from the pop-up menu (see ***Figure 2-38***):

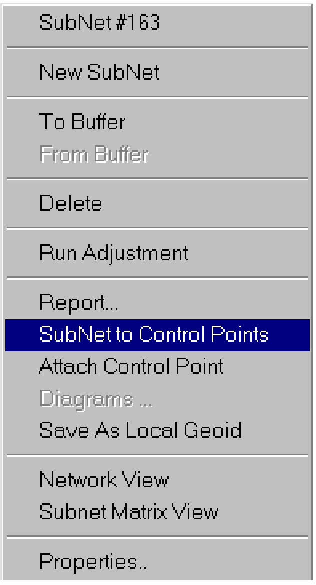
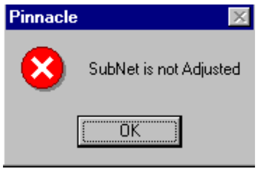


Figure 2-38

The '*Control Data*' window will appear as shown in ***Figure 2-39***:

[2]) Note that this feature is unavailable until the subnet is adjusted. If the user attempts to export a subnet that has not been adjusted, the following error message will be reported



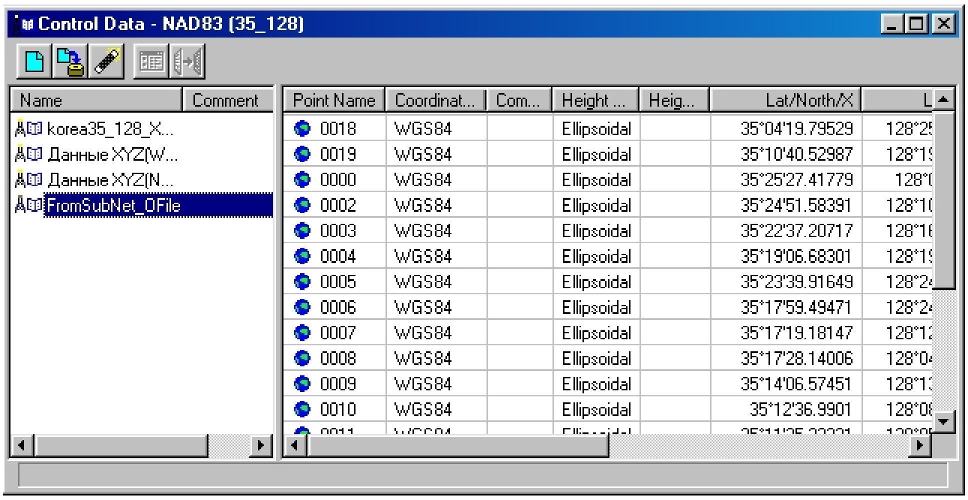
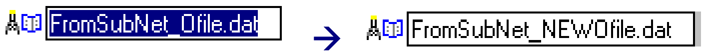


Figure 2-39

In the left-hand panel of this window, you will see a newly created control data list comprising the entire adjusted subnet. Note that the name of this new CDL is built by appending the subnet's name to the constant suffix '*FromSubNet*' (thus the CDL name *FromSubNet_Ofile* in our example).

You may want to rename this CDL. To do it, click on the CDL name in the left-hand panel of the '*Control Data'* window and type the new CDL name, e.g.:



To save a newly created CDL as a JPS Control Points file (*.jcp) file, right-click on its name, choose the '*Catalog Export to File*' option from the pop-up menu (see ***Figure 2-40***)

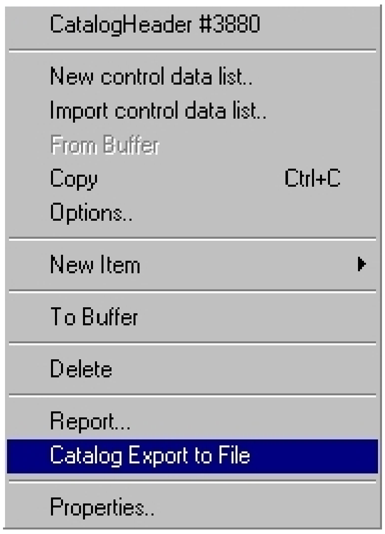


Figure 2-40

and finally specify the file name in the standard 'Save as' dialog window.

The user can employ this *.jcp file later when running another project.

2.6 Copying Control Data

Control Data Lists or individual Control Data Items may be copied by using the drag-and-drop technique:

- for *Control Data Lists*
  - o from one network into another network, or
  - o from a network into the project root and vice versa
- for *Control Data Items*
  - o from one CDL into another

2.7 Editing Control Data Lists or Control Data Items

Control data lists and control data items are Pinnacle objects and thus they have context menus associated with them. Throughout Pinnacle, such menus can be opened by right-clicking on the corresponding object.

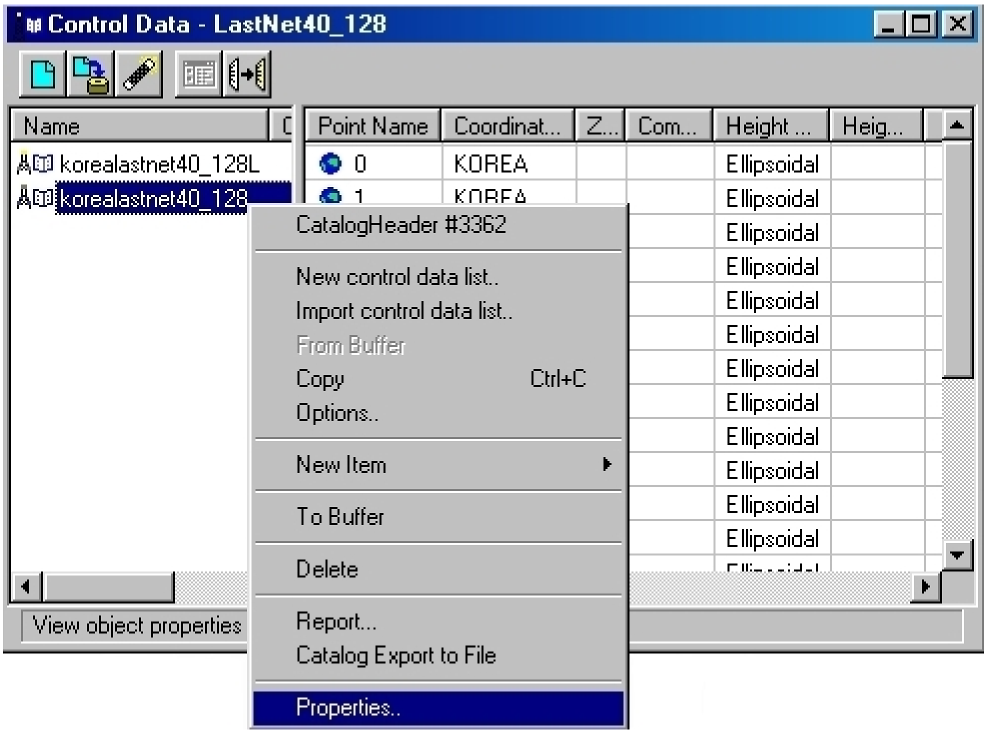


Figure 2-41

A CDL's context menu ("CatalogHeader") allows you to add a new item to the list, export this list as a *.jcp file and edit the list's properties.

To rename a CDL, you will need to select the '*Properties'* option from the corresponding context menu and then update the '*Name'* field in the '*General'* tab. It is also possible to edit the '*Comment*' field in this tab if required.

A control data item's menu ("CatalogItem") is used to add a new item to the list (you will need to select between '*Grid*', '*Geodetic*', and '*Cartesian*') or edit an existing item's properties (see ***Figure 2-42***):

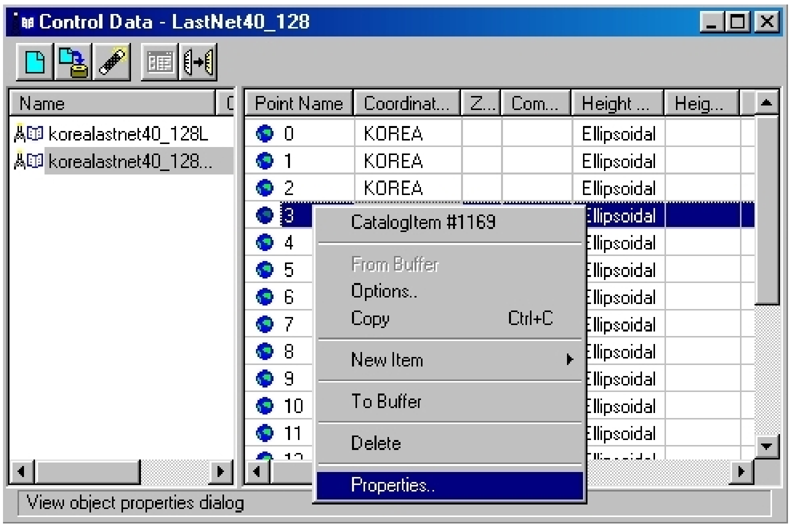


Figure 2-42

To edit control data items select the '*Properties'* option from this item's context menu to open the '*Properties for item of control point*' dialog window (see ***Figure 2-43*** for how Cartesian coordinates are handled in the '*General'* panel).

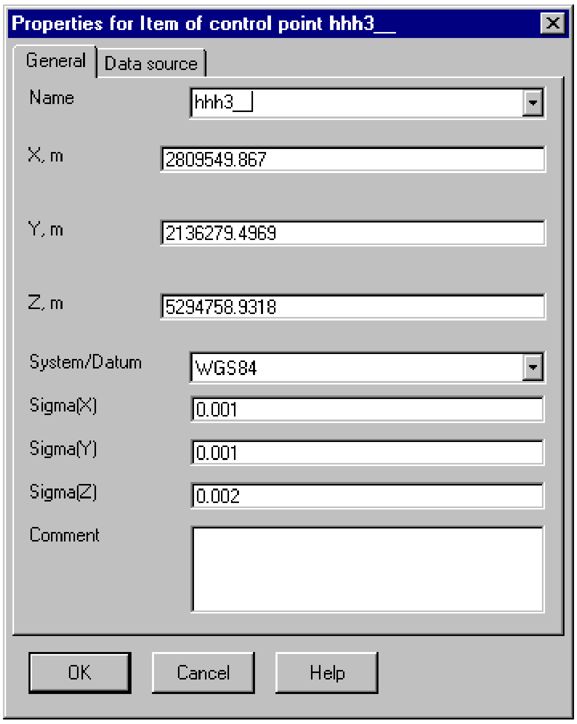


Figure 2-43

In the '*Data Source*' tab, the full path of the control data file will be displayed[3].

[3]) It holds true only for imported NGS datasheets (*.html). For other control data file formats, the user will need to use the '*Browse'* button to select the file path with the standard '*File*|*Open*' dialog box.

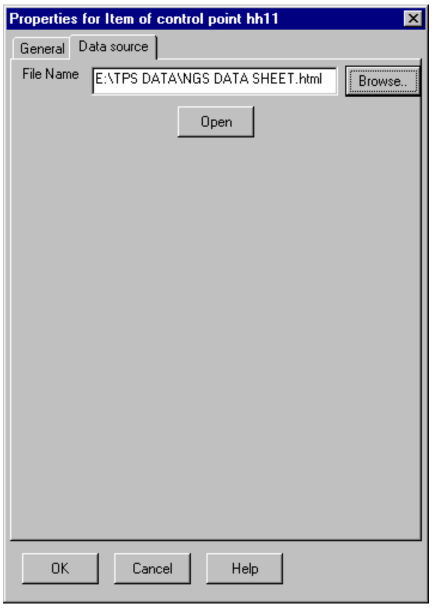


Figure 2-44

Once the control data file's full path is shown in the '*File Name*' field (see ***Figure 2-44***), you may open this file for viewing/editing. To do it, press the '*Open'* button to launch the file editor (specifically, the Windows application[4] that the extension of the given control data file is associated with).

Also,it is possible to edit an item's attributes (properties) directly in the right-hand panel of the '*Control Data*' window. To edit a property, highlight the corresponding field and then click on. You will then see an editbox or spinbox pop up:

- Control data item's name

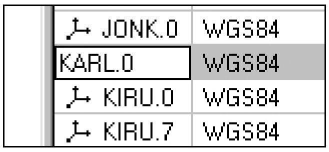


Figure 2-45

- Coordinate system/datum

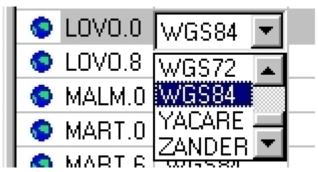


Figure 2-46

- Height type

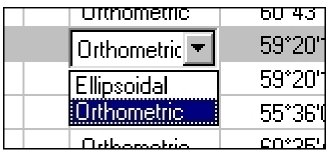


Figure 2-47

[4]) It may be '*Notepad'* or another text editor

- Coordinates (*x, y, z, lat, lon, ht*, etc.)

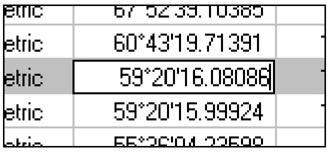


Figure 2-48

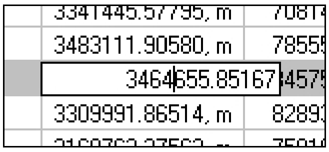


Figure 2-49

2.8 Deleting Control Data

The user may delete either an entire CDL or one or more of its items. To do it, use the '*Delete*' option from the context menu to be opened after right-clicking on the corresponding CDL in the left-hand panel (see ***Figure 2-50***) or item in the right-hand panel (see ***Figure 2-51***):

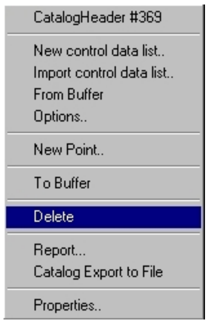


Figure 2-50

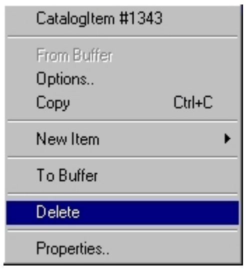


Figure 2-51

2.9 Select Property Types to be Displayed in the 'Control Data' Window

Youmay control the way in which the control data items' properties are shown on the screen. To customize the display of these data (items' properties) in the right-hand panel of the '*Control Data*' window, right-click anywhere in the left-hand panel of this window and choose '*Options…*' from the pop-up menu (see ***Figure 2-52***):

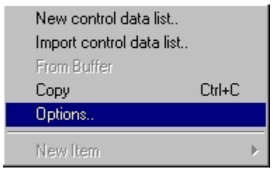


Figure 2-52

Next, select the desired checkboxes in the '*Control Data View Options*' dialog box in order to enable the display of the corresponding *property types* in the right-hand panel (see ***Figure 2-53***).

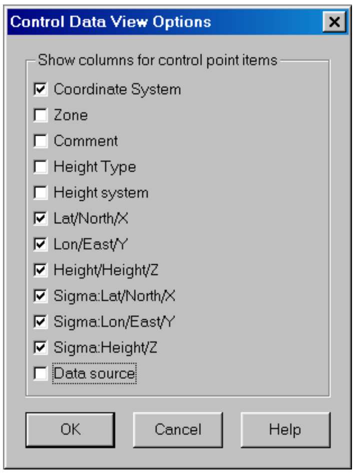


Figure 2-53

3 Attaching Control Data to GNSS Points

Control data can be accessed in different ways and from different parts of the project. Specifically, the user can access the '*Attach Control Point*' option

- For an individual network from the left-hand-most panel in the project's window (where the network tree is displayed)
- For an individual subnet in the '*Subnets'* panel (either through the subnet's context menu or by clicking on a specific point in the '*Network View*' window)
- For a vector's endpoint (for a specific solution in the *'Solutions'* panel)
- For an individual point (by using the '*Point Properties*' option for any one of the point's occupations in the '*Raw Data Sessions*' panel)

Control data attachment is a two-step procedure:

- Step#1: Select the *'Attach Control Point'* option from the context menu, activate the '*Attach points: Select Control Data Lists*' dialog window, and highlight the desired CDL.
- Step#2: Attach control data from the selected CDL to the desired points with the help of the '*Attach points to Control Point Items*' dialog box.

Note that the project's CDLs will have different scope depending on ***how*** they have been created.
Case#1. You can create a CDL effective for the entire project, i.e. for all of the networks that currently exist in the project or may be added to the project in the future. Such CDLs are marked with .
To create such a 'global' CDL:

- right-click on the project's node in order to activate the context menu (see ***Figure 3-1***),

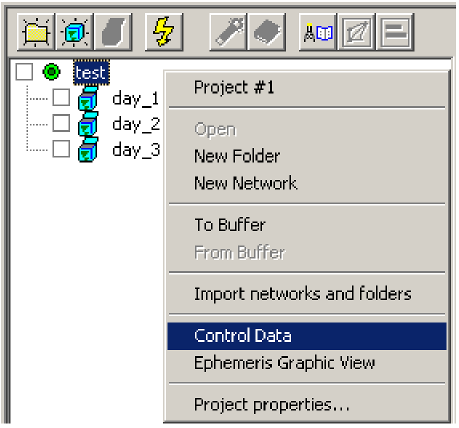


Figure 3-1

- select the '*Control Data*' option,
- after the '*Control Data* - `<Project Name>`' window is opened, right-click somewhere in an empty area of the window's left-hand panel
- select '*New Control Data List…*' from the pop-up menu.

Case#2. You can create a CDL effective only within a specific network. Such CDLs are marked with .
To create such a CDL:

- right-click on the network's node to activate the corresponding context menu (see ***Figure 3-2***),

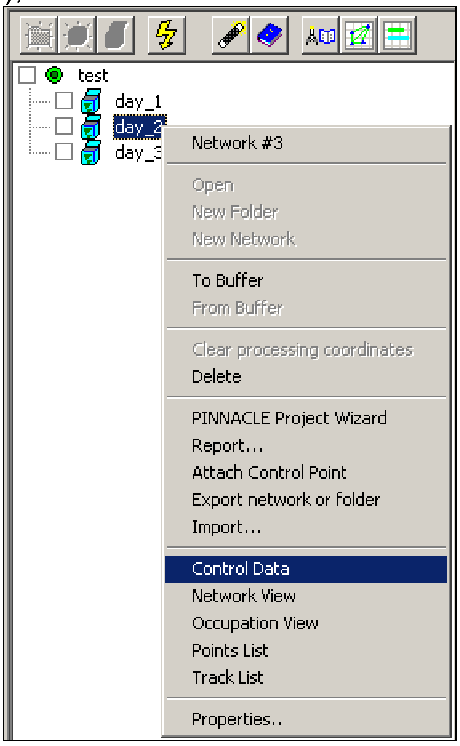


Figure 3-2

- the rest of the steps are as described above for Case#1

Next, we will explain how to attach control to GNSS points from *different* parts of the project's main window

- **Using the '*Attach Control Point*' option from a network's context menu (or from the pop-up menu activated by clicking on a point in the '*Network View*' window). See *Figure 3-2*.**

In this case the attached control data will be effective for the corresponding GNSS points <u>*only*</u> within the '*Raw Data Sessions*' and '*Solutions'* panels. However, the attached control <u>*will not be effective*</u> for these points within any one of the *existing* subnets (i.e. within the subnets created before this control has been attached). On the other hand, if youcreate a new subnet (containing these points) *after* performing the attachment, the control will be fully effective for this subnet's points.

- **Using the '*Attach Control Point*' option from a subnet's context menu (or from the pop-up menu activated by clicking on a point in the corresponding '*Network View*' window). See *Figure 3-3*.**

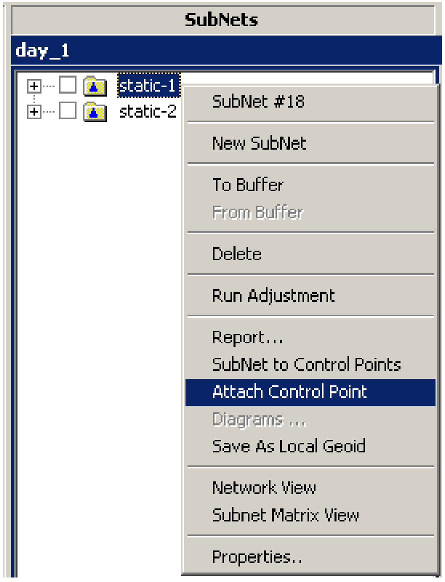


Figure 3-3

In this case the attached control data will be effective only for the given subnet.

- **Using the '*Attach Control Point*' option from a vector endpoint's context menu**

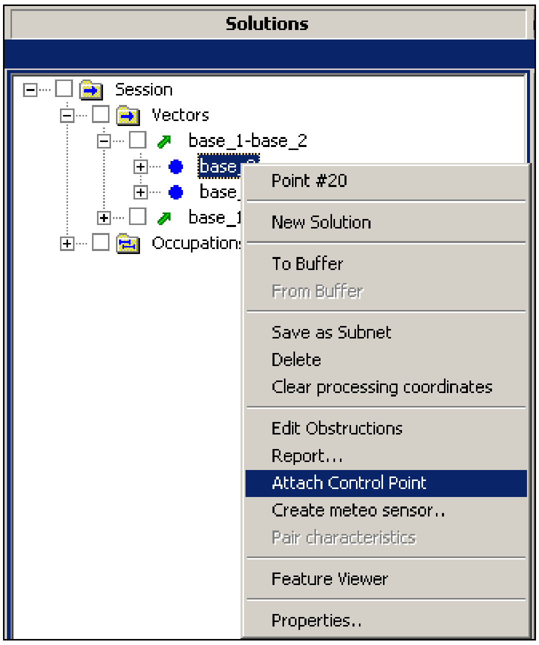


Figure 3-4

In this case the attached control will be effective for the corresponding points only within the '*Raw Data Sessions*' and '*Solutions'* panels (for the given network).

- **Using the '*Control coordinates*' tab in the '*Properties for Point <PointName>*' window**

In this case control data can be attached to the desired point through either the '*Solutions'* or '*Raw Data Sessions'* panel.

Right-click on any one of the occupation nodes corresponding to this point and choose the '*Point properties*' option from the pop-up menu. Go to the '*Control coordinates*' tab (see ***Figure 3-5***).

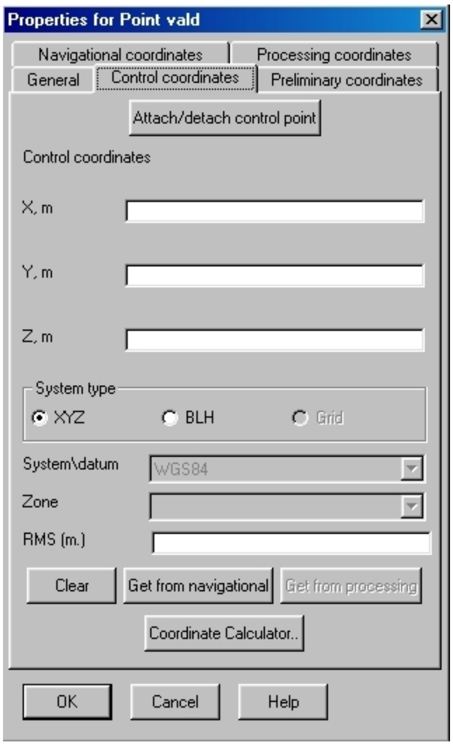


Figure 3-5

Press the '*Attach/detach Control Point*' button to activate the '*Attach points: Select Control Data Lists*' window.

Points with attached control will be marked with a blue triangle, ▲

3.1 Selecting more than one CDL at a time

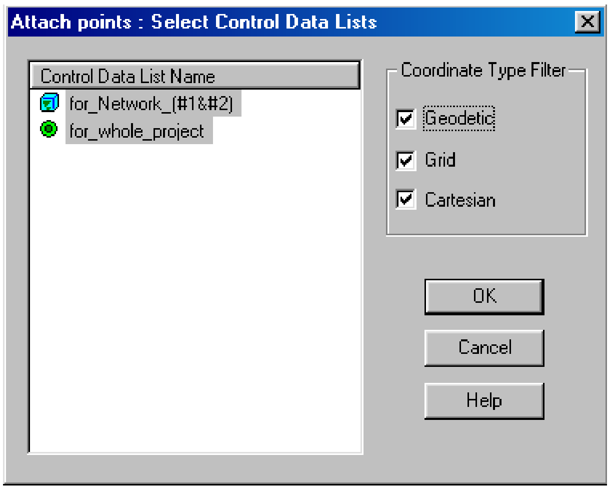


Figure 3-6

When the '*Attach points: Select Control Data Lists*' dialog box is opened, the user can highlight multiple CDLs at a time. To do it, the user must click on the desired list names while holding down the 'Shift' or 'Ctrl' key.

3.2 'Attach Points to Control Point Items' dialog window

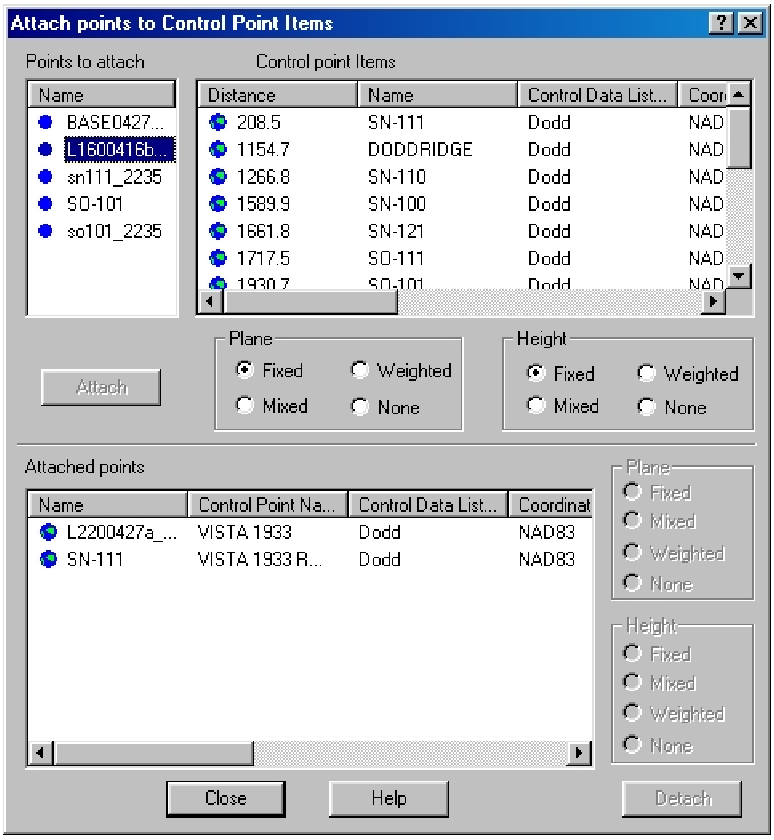


Figure 3-7

The top-left '*Points to attach*' panel shows a list of points to which control can be attached.

The top-right '*Control point Items*' panel shows the control point items available in the selected CDL.

The bottom panel, called '*Attached points*', lists all of the points to which control has already been attached.

When you select a point from the '*Points to attach*' list, the program will automatically sort the control point items according to their distance to the selected point.

You can select a control point item by clicking on it (in the area right under the *Distance* title).

The '*Plane'* and '*Height'* radio button groups are used to specify the status of the horizontal and vertical control, specifically: '*Fixed'*, '*Mixed'*, '*Weighted'* or '*None'*.

If '*Fixed'* is selected, the point's coordinate(s) will be treated as 'fixed' (precisely known) when performing a constrained adjustment.

If '*Weighted*' is selected, the control data will be weighted according to the specified standard errors.

If you choose '*Mixed'*, the control data will be treated as either fixed or weighted depending on the selected adjustment type.

If you select '*None'*, the corresponding component of the control coordinates will not be used in the adjustment.

After the desired radio buttons are selected, press the '*Attach'* button to enable the newly attached control. You will then see the new item appear in the '*Attached points*' panel.

To change the current status of the attached control, use the '*Plane'* and '*Height'* radio buttons associated with the '*Attached Points'* panel.

The '*Detach'* button is used to disable the previous status of the attached control.

To complete the control attachment procedure, click the '*Close'* button.

Pinnacle™
Reference Documentation Suite

Coordinate Transformations and Geoid Models

User's Manual

This document reflects
the interim (mid-October 2001) version
of Pinnacle 1.0

Last revised December 1, 2001

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Table of Contents

1. *Introduction*

Pinnacle allows the user to apply coordinate transformations to the following four coordinate types:

1. 3-D Cartesian coordinates
2. Geodetic coordinates: *latitude*, *longitude*, *ellipsoidal height*;
3. Grid coordinates: the *plane* coordinates *Northing* and *Easting* are based on a map projection, the third coordinate is *Orthometric Height.*
4. Local coordinates (arbitrarily called *x, y* and *height)*.

The first two coordinate types depend on the selected datum.

A grid coordinate system depends on the selected datum, projection type and zone.

A local coordinate system is considered as "a ground-level coordinate system" that is not formally associated with any known geodetic datum.

Pinnacle's *built-in* Coordinate Transformation Library is used to accomplish several different tasks.

Note that there are three buttons on the main window's toolbar that are intended to transform coordinates, specifically , and .

To start the '*Coordinate system and Geoid*' editor, press the button on the main window's toolbar. The '*Coordinate System and Geoid Editor'* dialog window will be opened.

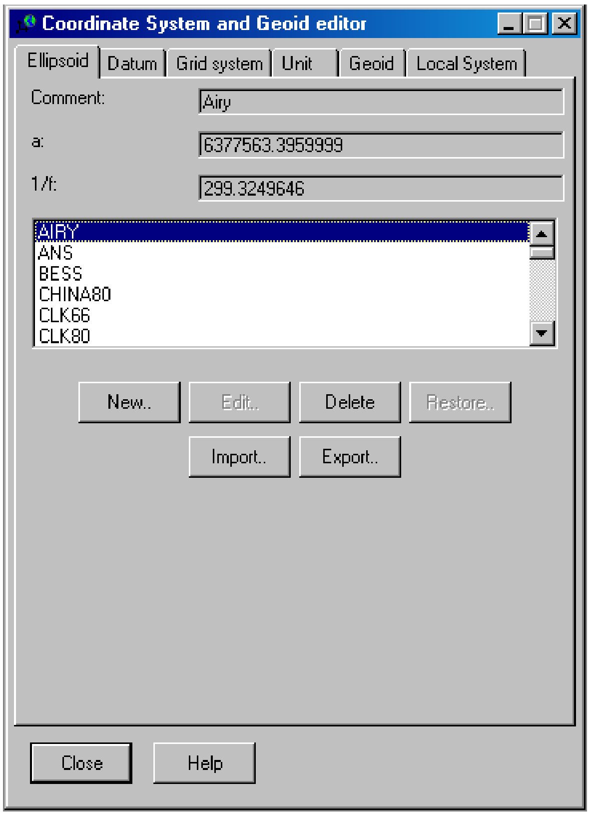


Figure 1-1

This window allows the user to:

- View, hide, import and export the pre-defined ellipsoids, datums, grid systems, geoids and linear units of measurement
- Add, edit, delete, import and export the user-defined ellipsoids, datums, grid systems, local systems, geoids and linear units of measurement

Afurther two buttons on the toolbar, *Coordinate Calculator* and *Table Coordinate Calculator*, allow coordinate transformation for a single point or a list of points, respectively.

2. *Ellipsoids*

Press the main window's ***'Coordinate System Editor'***  button and choose the ***'Ellipsoid'*** tab. The following dialog window will be opened:

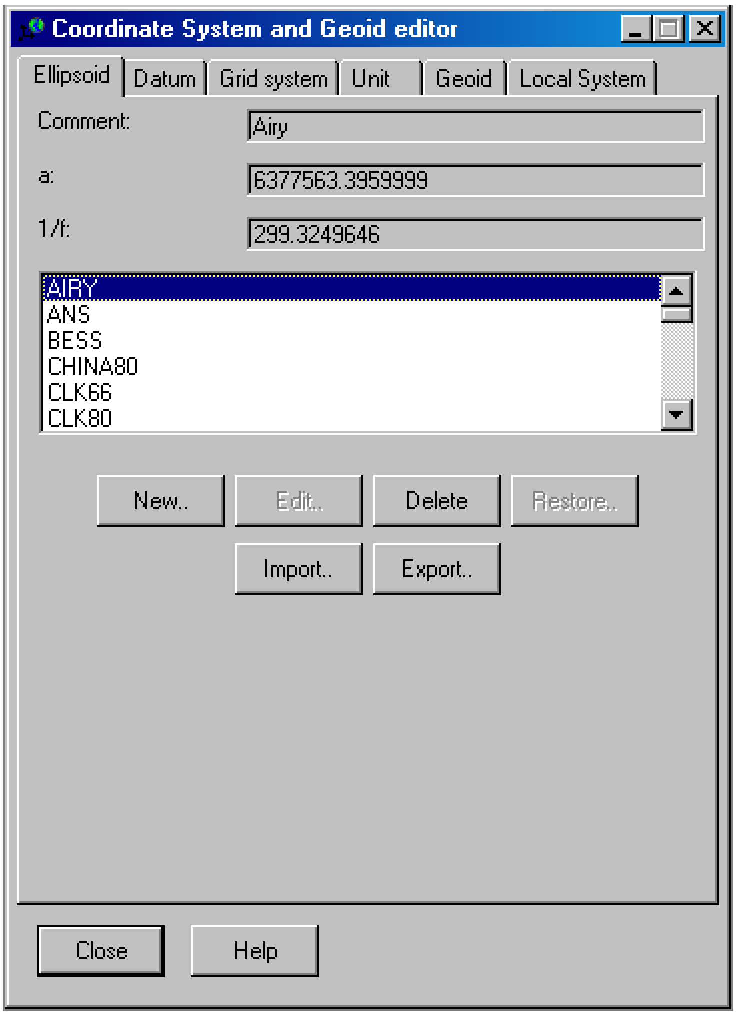


Figure 2-1

The ***'Ellipsoid'*** tab allows the user to

- View, hide, import and export the pre-defined ellipsoids,
- Add, edit, import, export or delete the user-defined ellipsoids.

PINNACLE installation includes a list of the predefined ellipsoids which can be used but not modified or removed from the database. The user can temporarily 'hide' a pre-defined ellipsoid so that it will not be explicitly shown in any ellipsoid lists throughout Pinnacle (note that this pre-defined ellipsoid can be restored later).

The ***'Ellipsoid'*** tab provides basic information about the selected ellipsoid, specifically: its semi-major axis and reciprocal flattening (**1/f**) preceded by a comment. The user can either choose an ellipsoid from the list box (in order to view or edit its parameters) or create a new one.

Note: Only the user-defined ellipsoids can be edited.

New user-defined ellipsoids can be added through the ***'Ellipsoid'*** dialog box (with the ***'New…'*** button). Only the user-defined ellipsoids may be edited or deleted.

The following buttons are used in the ***'Ellipsoid'*** tab:

- ***'New…'*** button is used to create a new ellipsoid:

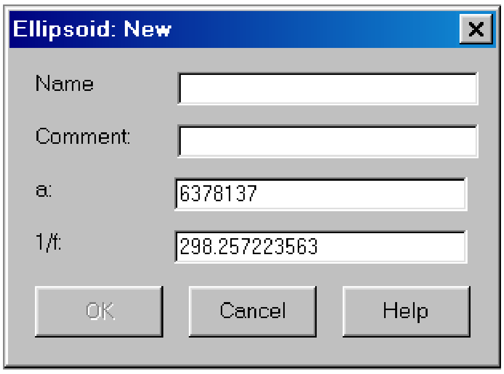


Figure 2-2

Enter the ellipsoid's name in the ***'Name'*** field and modify the values of ***a*** and ***1/f***, if required (the WGS84 constants are used by default).

Press the ***'OK'*** button to add this new ellipsoid to the existing list.

- ***'Edit…'*** button is used to edit a user-defined ellipsoid

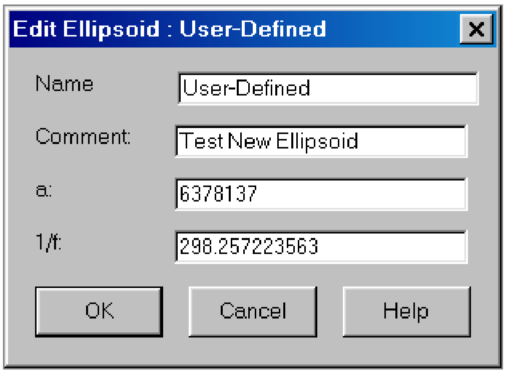


Figure 2-3

The user can modify any one of the displayed values if required.

After updating the ellipsoid parameter, press the ***'OK'*** button.

- ***'Delete'*** button allows the user to delete a user-defined ellipsoid or 'hide' a pre-defined ellipsoid.

If a user-defined ellipsoid is selected and then the ***'Delete'*** button is pressed, the following dialog window will appear:

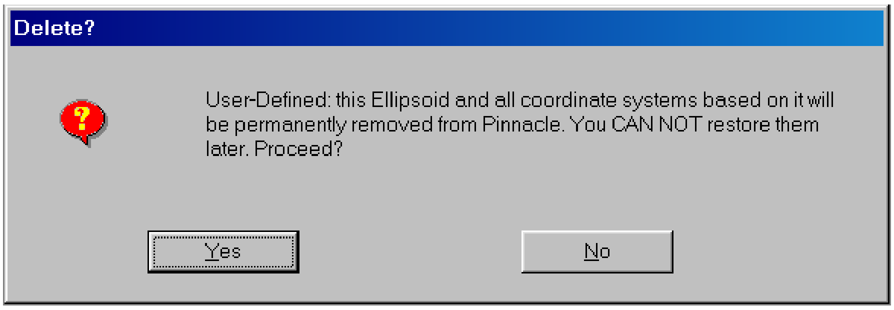


Figure 2-4

Note that if the user presses the ***'Yes'*** button, the selected user-defined ellipsoid and all of the coordinate systems referenced to it will be permanently removed.

The user cannot delete any pre-defined ellipsoids but can hide one or more pre-defined ellipsoids from all ellipsoid lists throughout Pinnacle. To do this, the user must highlight the desired ellipsoid(s) in the list box as shown in Figure 2-5:

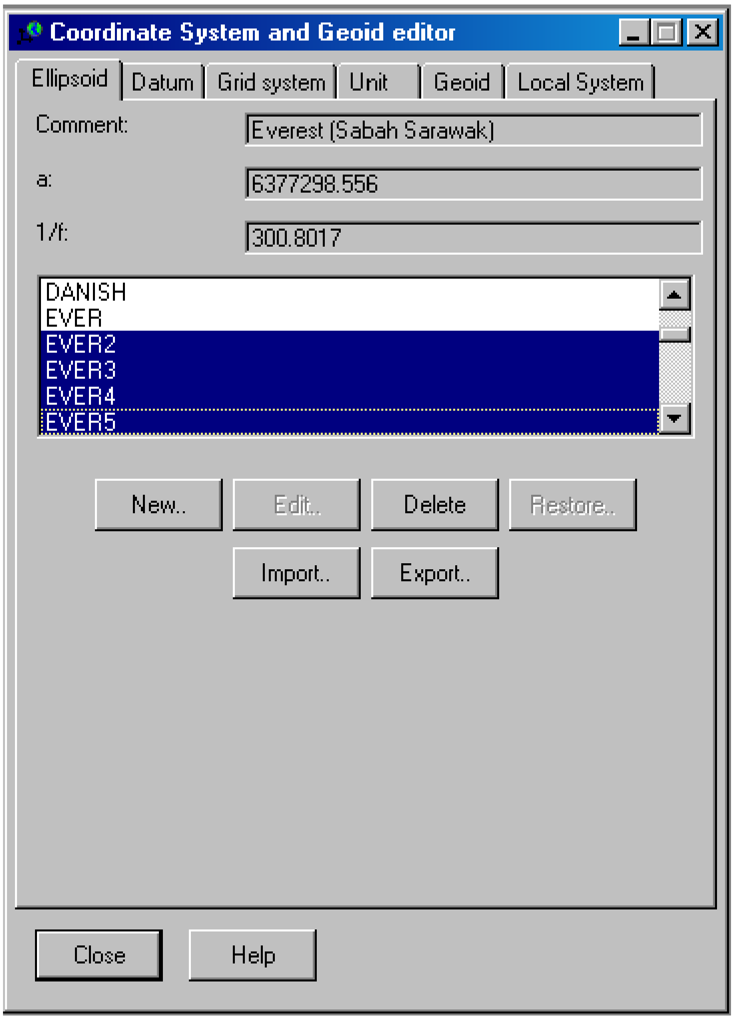


Figure 2-5

and then press the ***'Delete'*** button. The following dialog window will then pop up :

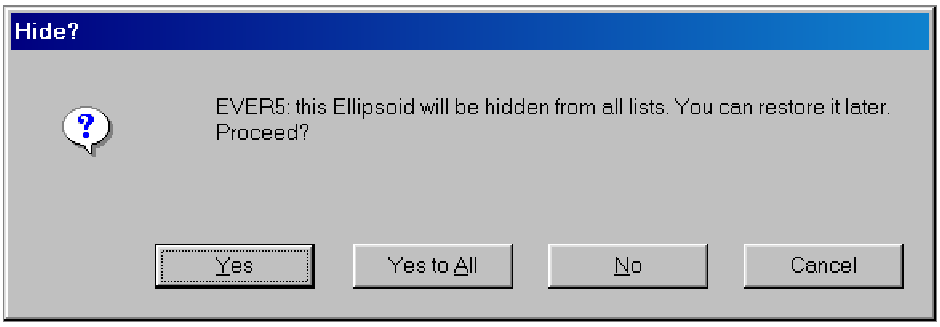


Figure 2-6

Note that all of the hidden pre-defined ellipsoids can be restored later.

- ***'Restore…'*** button is used to restore (unhide) some or all of the hidden pre-defined ellipsoids.

  If there are any hidden pre-defined ellipsoids in Pinnacle, the ***'Restore…'*** button will be active:

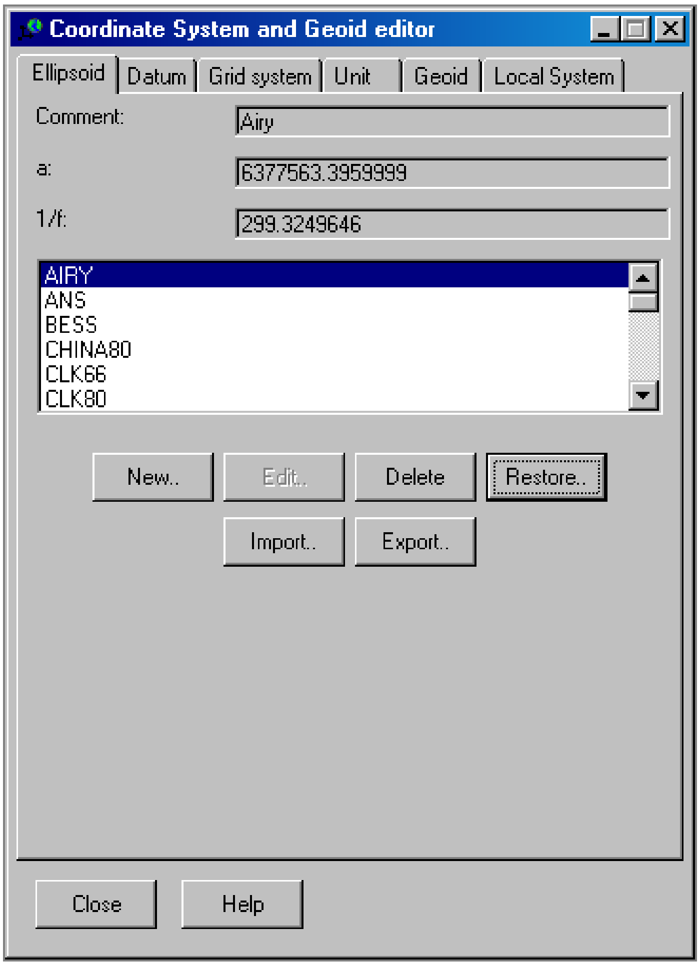


Figure 2-7

If the ***'Restore…'*** button is pressed, the following dialog window will appear:

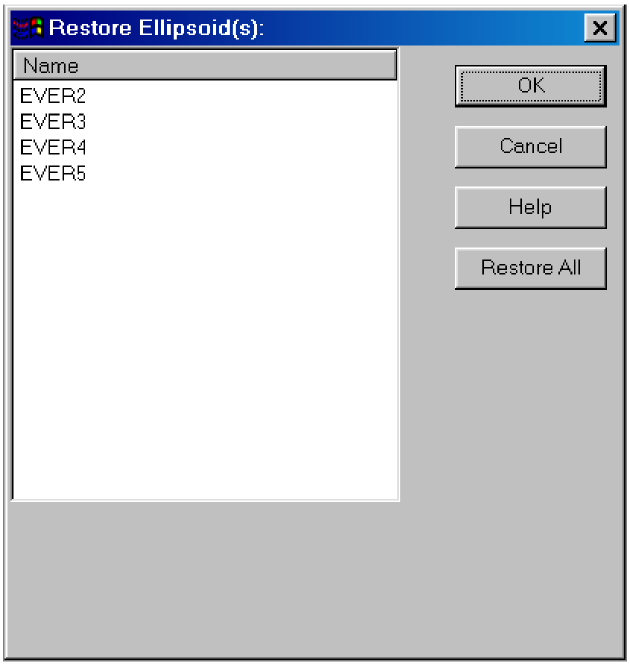


Figure 2-8

The user must select the ellipsoid(s) he/she wants to unhide and press ***'OK'.*** To restore all of the hidden pre-defined ellipsoid, use the button ***'Restore All'***.

- ***'Import…'*** button is used to import a *Pinnacle Ellipsoid* file (such files have the extension ****.jff***).

  Pressing this button will invoke the standard '*File|Open'* dialog box.

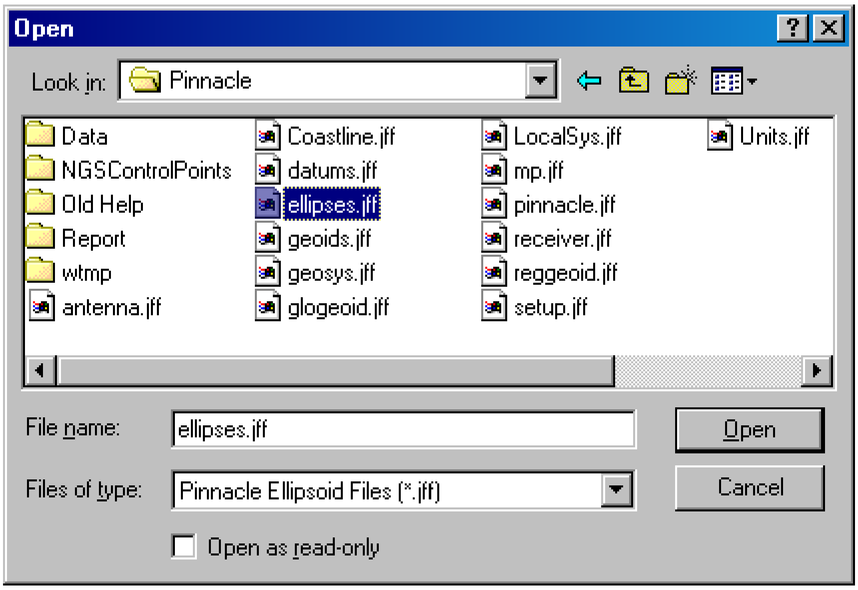


Figure 2-9

This dialog box allows the user to select the desired pinnacle ellipsoid file (note that the PINNACLE installation includes the file *ellipses.jff*).

- ***'Export…'*** button is used to export the ellipsoid parameters into a *Pinnacle Ellipsoid* file (such files have the extension ****.jff***).

  Pressing this button will invoke a standard *'Save As'* dialog box.

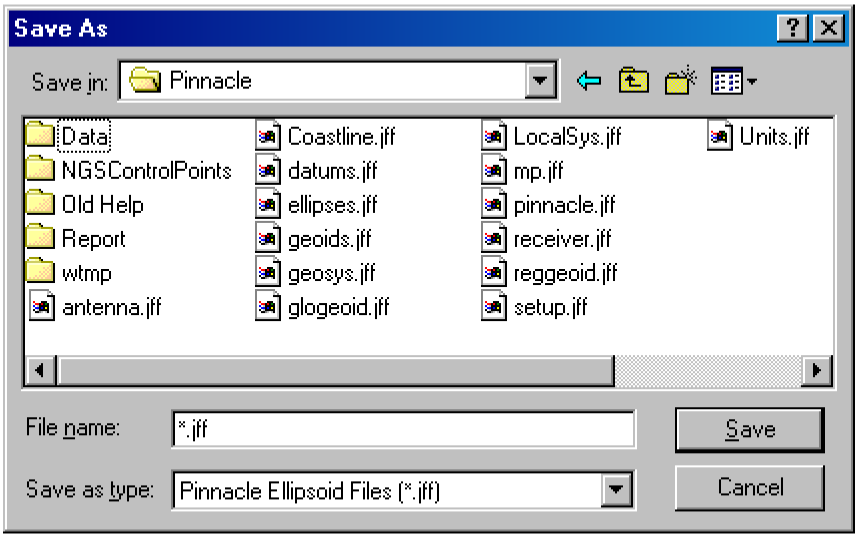


Figure 2-10

This dialog box allows the user to select an existing, or create a new, *Pinnacle Ellipsoid* file.

When the user exports a pre-defined ellipsoid, the following dialog box appears:

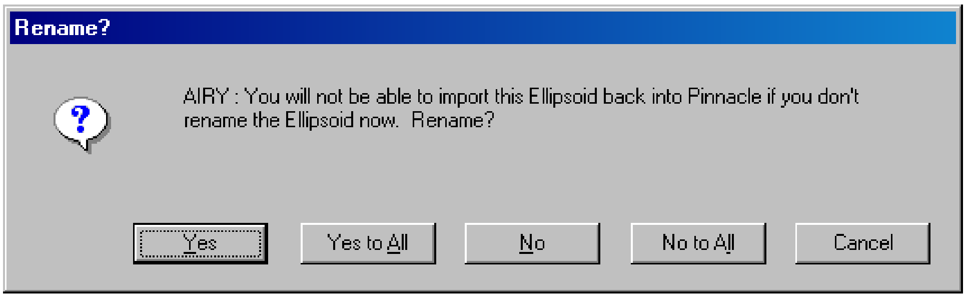


Figure 2-11

If either the *'Yes'* or *'Yes all'* button is pressed, the following dialog box appears:

Figure 2-12

This window allows the user to rename the ellipsoid.

3. *Datums*

Press the *Coordinate System Editor* button in Pinnacle's main toolbar, and choose the ***Datum*** tab to:

- View, hide, import and export the pre-defined datums
- Add, edit, import, export or delete the user-defined datums.

PINNACLE offers a list of the pre-defined datums which can be used but not modified or removed from the database.

Note that only the user-defined datums may be edited or deleted.

New user-defined datums can be added to the list with the ***'New…'*** button (see Figure 3-1):

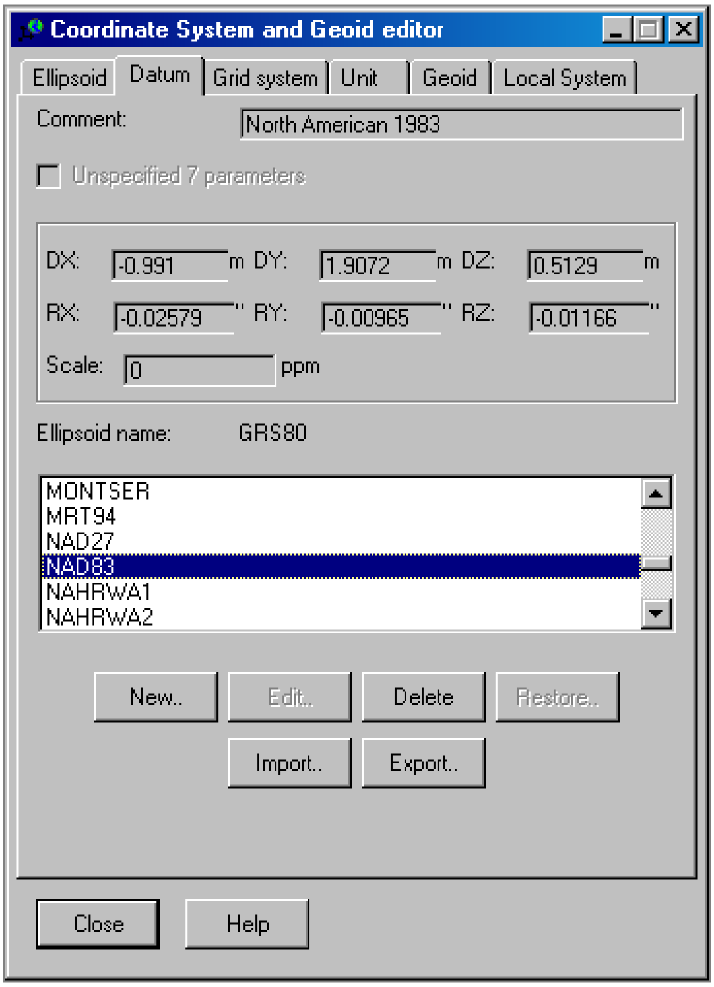


Figure 3-1

The ***Datum*** tab will provide the user with the following basic information about the selected datum:

- Datum's full name. This parameter, which is optional, is shown in the '*Comment'* field.
- *Translation parameters* defining the position of the reference ellipsoid's center relative to WGS84's origin. These three scalars are specified in meters.
- *Rotation angles* defining the orientation of the reference ellipsoid relative to WGS84's axes. These three scalars are specified in arc seconds.
- *Scale factor* (in ppm);
- Reference ellipsoid's *name*.

Note that Pinnacle also allows '*unspecified'* user-defined datums. An unspecified datum means that only two parameters are defined for this datum, specifically: the datum name and reference ellipsoid. No transformation parameters are specified for this datum. Note however that the user can specify the absent parameters later by computing a 7-parameter transformation between WGS84 and this datum.

***Note:** Coordinate transformations between two datums are **not valid** in the following two cases:*

(1) two different unspecified datums are used

(2) the first datum is 'normal' while the other is unspecified

The following explains what purposes the buttons available in this tab serve.

- ***'New…'*** button allows the user to create a new datum.

  If this button is pressed, the following dialog box will appear (see Figure 3-2):

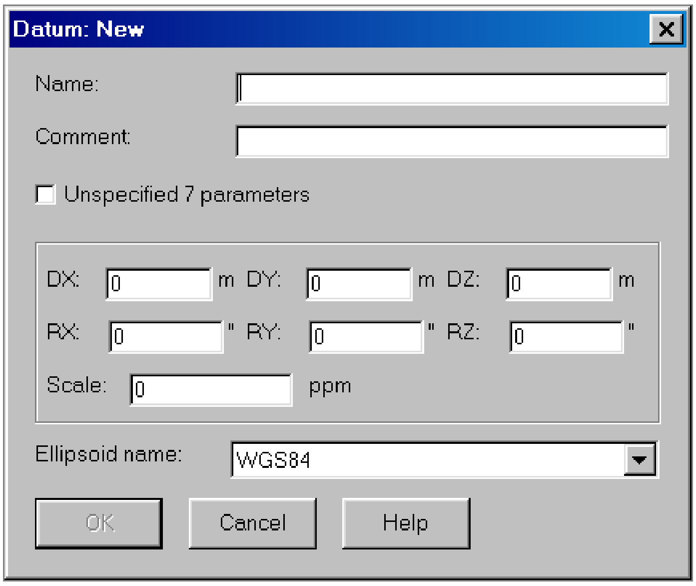


Figure 3-2

Enter the desired name in the '*Name'* field and type the values of *DX, DY, DZ, RX, RY, RZ* and *Scale* (which are all zeros by default).

Note that these parameters (translations, rotations and scale) specify a coordinate transformation ***from*** the newly created reference datum ***to*** WGS84 according to the following equations:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} = \begin{bmatrix} DX \\ DY \\ DZ \end{bmatrix} + (1 + Scale \cdot 10^{-6}) \cdot \begin{bmatrix} 1 & RZ & -RY \\ -RZ & 1 & RX \\ RY & -RX & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{referenceDatum}$$

For an unspecified datum, select the '*Unspecified 7 parameters'* checkbox.

Next select the desired reference ellipsoid from the '*Ellipsoid Name'* list box (WGS84 by default).

Press the '***OK***' button to add the newly created datum to the existing ones.

- ***'Edit…'*** button is used to edit a user-defined datum (see Figure 3-3).

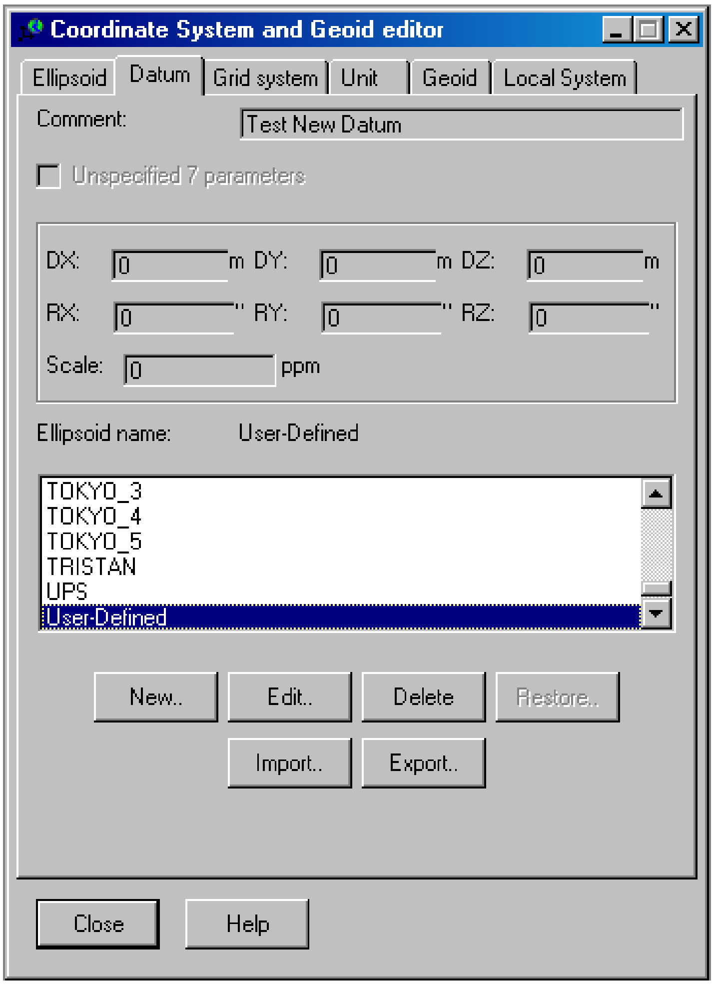


Figure 3-3

After pressing this button, the following dialog box will pop up (see the example in Figure 3-4):

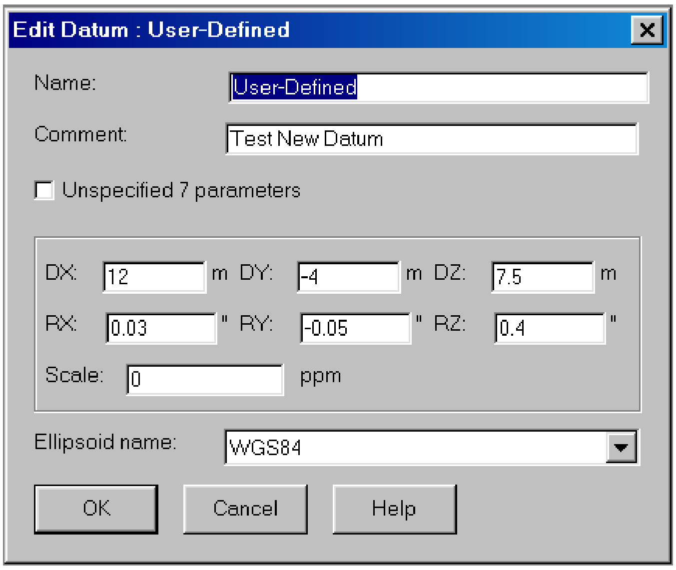


Figure 3-4

Edit the displayed values where required.

Press the ***'OK'*** button to update the selected datum.

- ***'Delete'*** button is used to delete user-defined and hide pre-defined datums in Pinnacle.

  If a user-defined datum has been selected and the ***'Delete'*** button is then pressed, the following prompt will appear (see Figure 3-5):

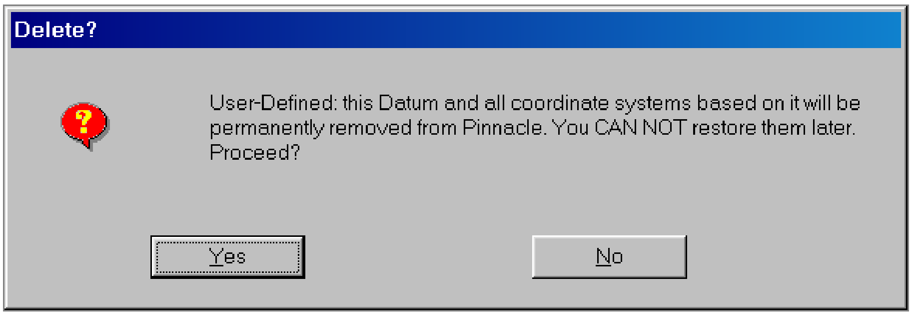


Figure 3-5

Note that if the user clicks the ***'Yes'*** button, the corresponding user-defined datum and all of the coordinate systems referenced to this datum will be permanently removed from Pinnacle's database.

The user cannot delete a pre-defined datum but it is possible to make a pre-defined datum or a group of predefined datums 'hidden' when displaying the lists of such datums in the corresponding dialog windows throughout Pinnacle.

To make one or more of the pre-defined datums hidden in any of Pinnacle's dialog windows where the pre-defined datums are listed, the user will

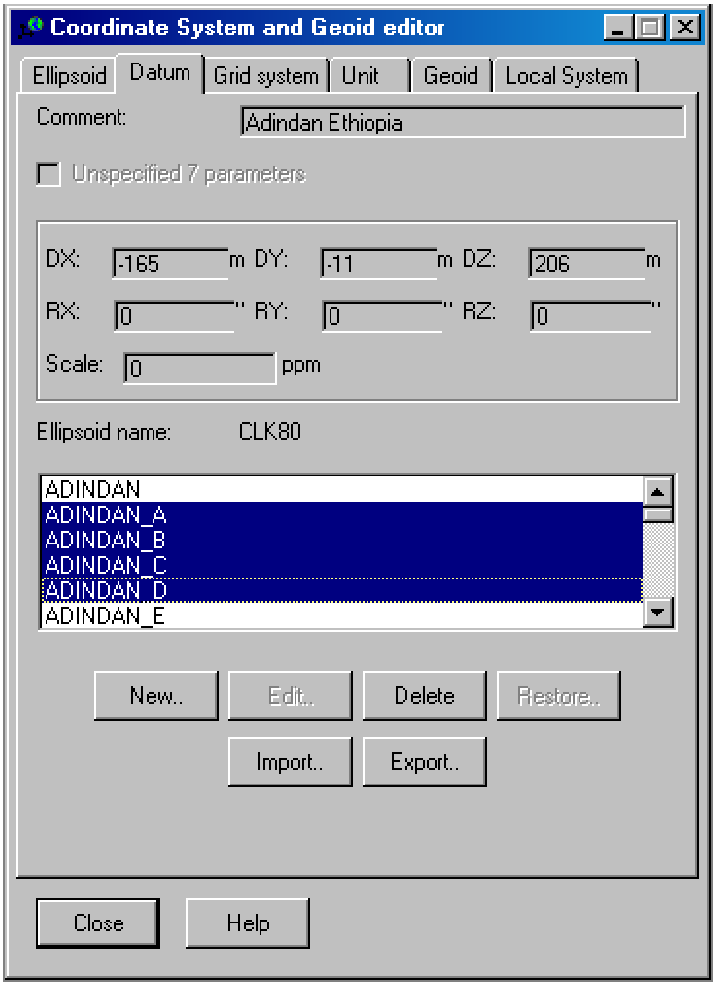


Figure 3-6

need to highlight these datums and then press ***'Delete'***. The following prompt will pop up (see the example in Figure 3-7):

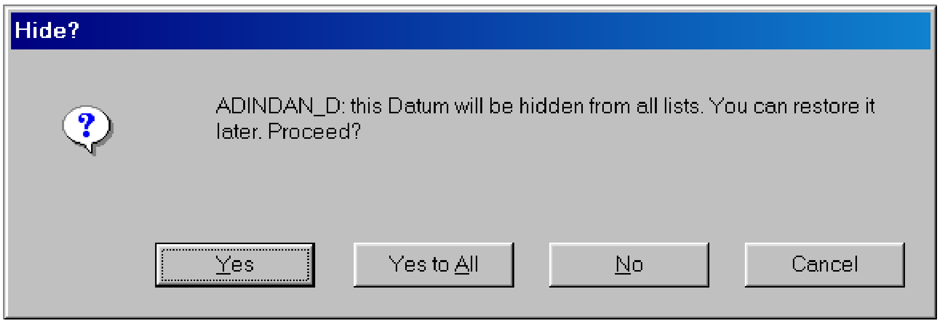


Figure 3-7

Note that all hidden pre-defined datums can be restored later.

- ***'Restore…'*** button is used to restore (unhide) one, or more than one, hidden pre-defined datum.

If there are any hidden pre-defined datums in Pinnacle, the ***'Restore…'*** button will be active as shown in Figure 3-8:

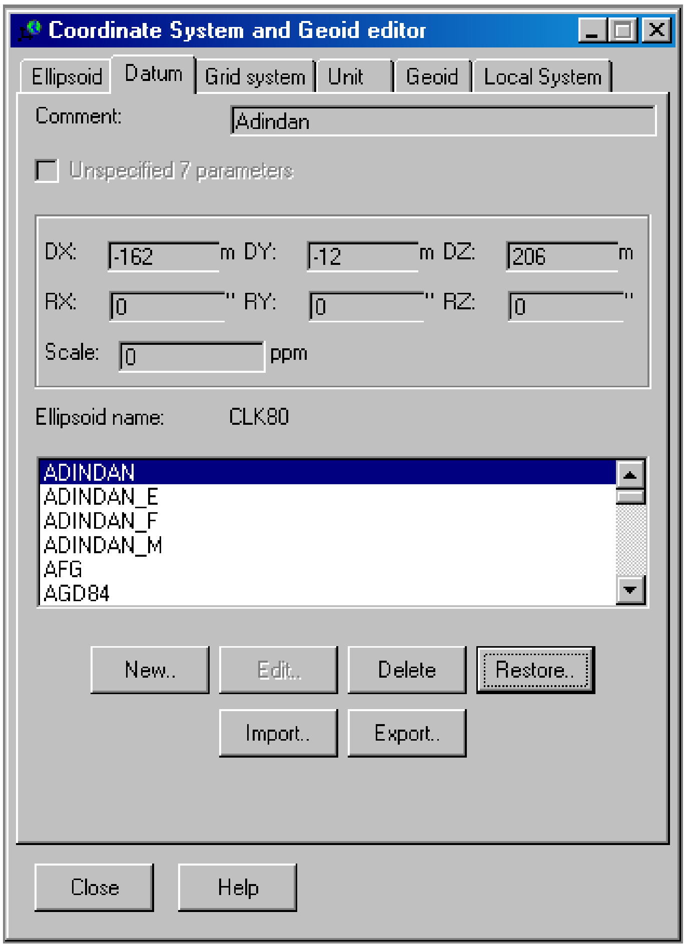


Figure 3-8

Once the ***'Restore…'*** button is pressed, the following dialog window will pop up (see Figure 3-9):

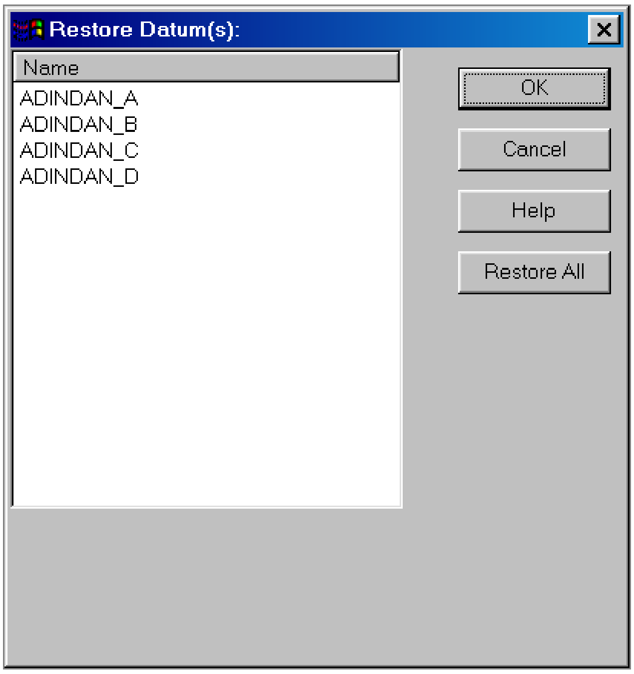


Figure 3-9

Here the user must select the datums that (s)he wants to restore and then press ***'OK'***. The button ***'Restore All'*** is used, as its name implies, to restore all of the hidden datums at once.

- ***'Import'*** button is used to import a *Pinnacle Datum* file (such files have the extension ****.jff***).

Press this button to invoke the standard '*File|Open'* dialog box as shown in Figure 3-10 .

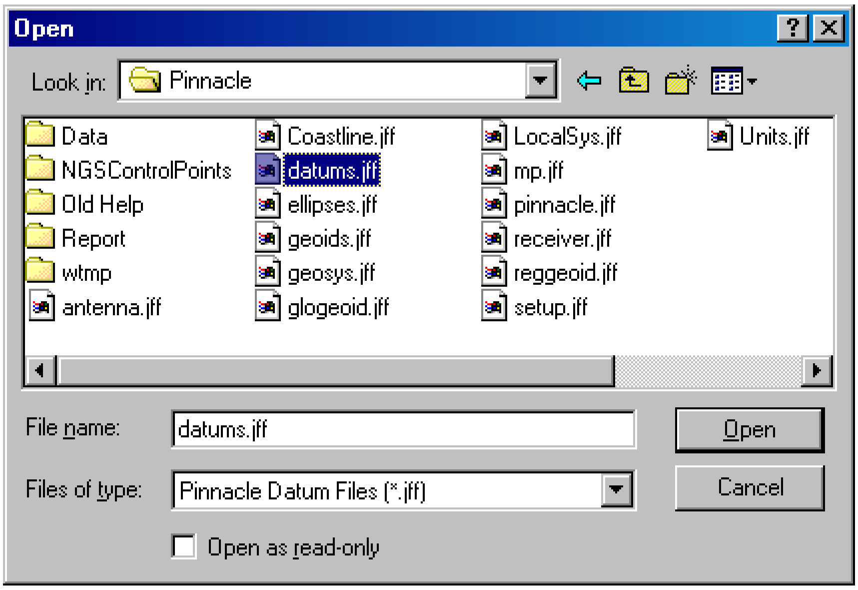


Figure 3-10

Select the desired pinnacle datum file from the listbox. Note that the PINNACLE installation includes the file *datums.jff*.

- ***'Export…'*** button is used to export the datum parameters into a *Pinnacle Datum* file (such files have the extension ***.jff***).

Pressing this button will invoke a standard *'Save As'* dialog box.

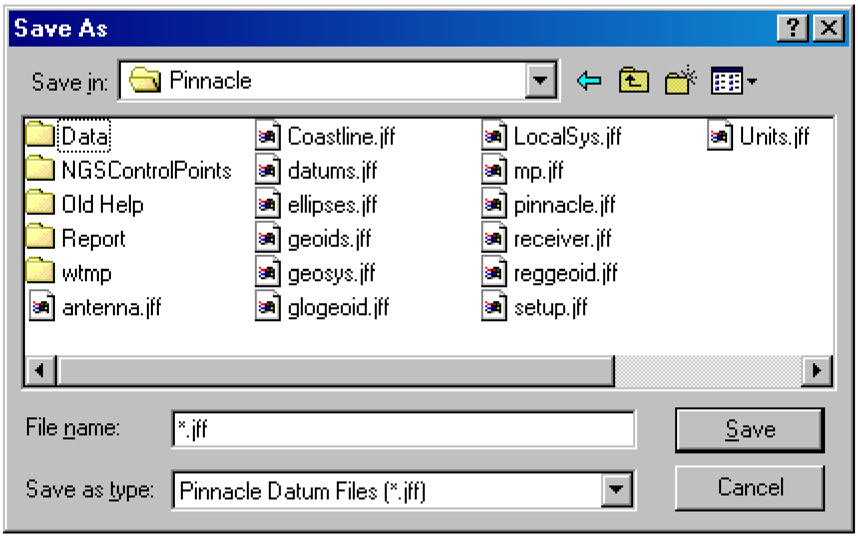


Figure 3-11

This dialog box allows the user to select an existing, or create a new, *Pinnacle Datum* file.

When the user exports a pre-defined datum, the following dialog box appears:

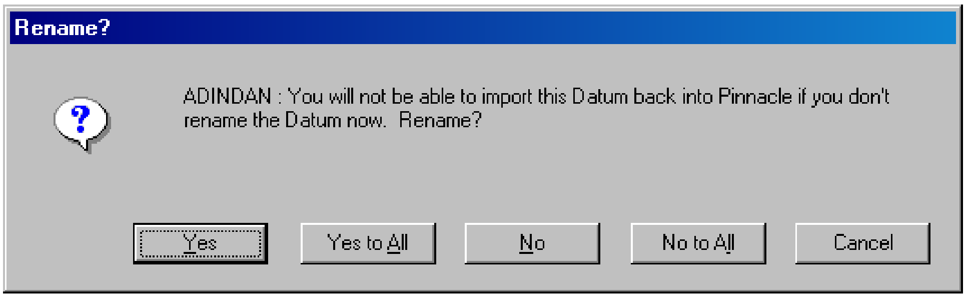


Figure 3-12

If either the *'Yes'* or *'Yes all'* button is pressed, the following dialog box appears:

Figure 3-13

This window allows the user to rename the datum.

4. *Grid Systems*

Press the ***'Coordinate System Editor'*** button  on the main window's toolbar and choose the ***'Grid System'*** tab to:

- View, hide, import and export the pre-defined grid systems
- Add, edit, import, export or delete user-defined grid systems.

PINNACLE offers a list of the pre-defined grid systems which can be viewed or made 'hidden' but which cannot be modified or removed from the database.

The ***'Grid System'*** tab allows creation of new user-defined grid systems as well updating or deletion of the existing user-defined grid systems.

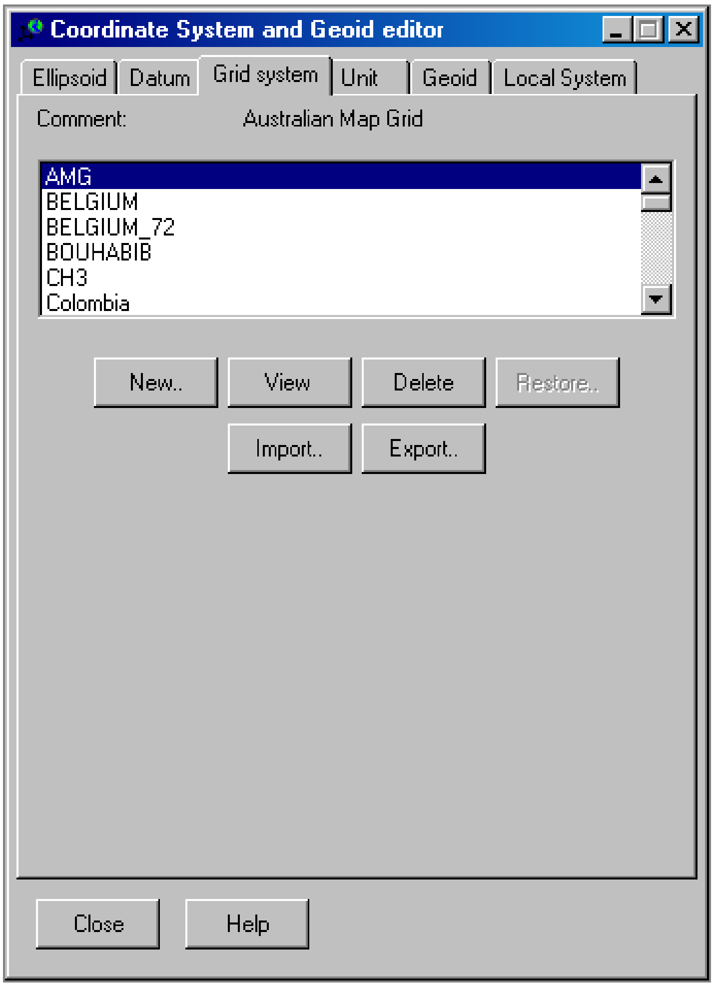


Figure 4-1

This tab displays a list of the grid systems available in Pinnacle (see the listbox at the top of Figure 4-1). Each grid system will have a unique identification in the list. Grid systems may or may not have their full names in the database. If a highlighted grid system has a full name, this name will be shown in the '*Comment'* field at the top of the window.

Every grid system has, by definition, the following properties (attributes):

- Grid system's identification
- Comment. This parameter, which is optional, normally serves as the grid system's full name.
- One or more than one zone where the grid system is defined (effective).

The following explains how buttons available in the '*Grid Systems'* tab are used.

- ***'New…'*** button is used to create a new grid system;
- ***'View / Edit…'*** button is used to view or edit a selected grid system (depending on whether this grid system is pre-defined or user-defined, respectively).
- ***'Delete'*** button is used to delete one, or more than one, user-defined system, or to hide one or more than one pre-defined grid system when listing such grid systems in Pinnacle's dialog windows. Note that the hidden pre-defined grid systems can be restored (unhidden) later.
- ***'Import'*** button allows import of a Pinnacle Grid System File;
- ***'Restore…'*** button allows the user to restore one or more than one hidden pre-defined grid system.

4.1. How to create a new user-defined grid system

The ***'New…'*** button of the '*Grid System'* tab is used to create a new grid system. Pressing this button will invoke the following dialog window (see Figure 4-2):

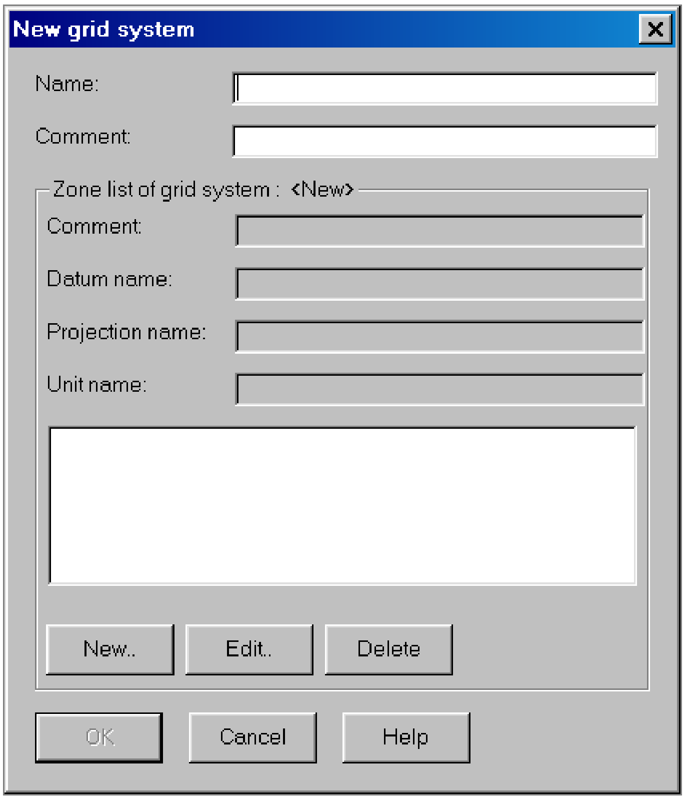


Figure 4-2

The user must enter the grid system's name and an appropriate comment if required. Further, the user will need to press the ***'New…'*** button in order to open the '*Zone list of grid system'* group box (see Figure 4-3):

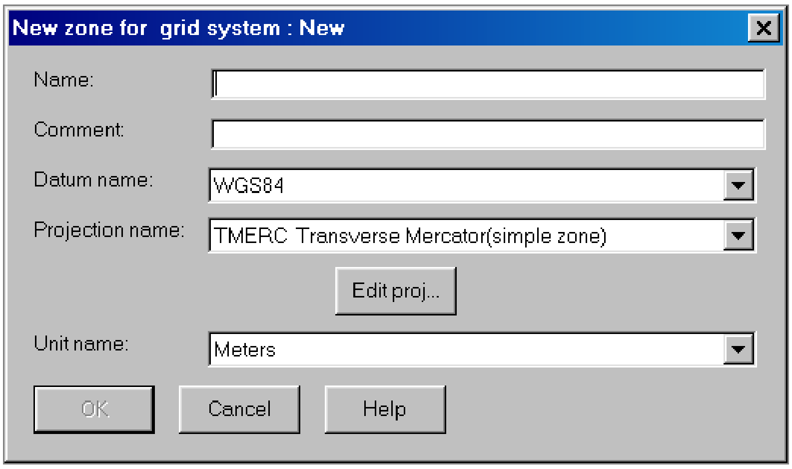


Figure 4-3

The user must first type the new zone's name in the '*Name'* field and then, optionally, the zone's full name in the '*Comment*' field. Next, the user will need to select the desired datum from the '*Datum Name'* listbox, projection type from the '*Projection name'* listbox and, finally, the unit of measurement from the '*Unit Name'* listbox.

Note that WGS84, TMERC Transverse Mercator and meters are used by default.

Pressing the ***'Edit proj...'*** button will bring up the dialog window where the user must set up the selected projection type.

Pinnacle's built-in *Coordinate Transformation Library* comprises the following projection types:

Acronym	Projection name
AK01	Alaska Zone 1 (SPC27)
AK29	Alaska Zone 2-9 (SPC27)
ALBERS	Albers equal-area projection
BONNE	Bonne projection
C_S	Cassini-Soldner projection (for Malaysia)
CASSINI	Cassini projection
COLOMBIA	Cartesian Cartographic projection (Colombia)
EQD_AZMT	Azimuthal-Equidistant projection
EQD1	Equidistant projection with one standard parallel
EQD2	Equidistant projection with two standard parallels
LC	Lambert conformal projection with two standard parallels
LC_1	Lambert conformal projection with one standard parallel
LC27	Lambert conformal for the SPC27 system
LC83	Lambert conformal for the SPC83 system
MERC	Mercator projection
OM	Oblique Mercator projection
OM_2	Oblique Mercator projection (2 points)
OM83	Oblique Mercator projection for the SPC83 system
RSO	Rectified Skew Orthomorphic projection (for Malaysia)
SINUS	Sinusoidal projection
STER	Stereographic projection
STER70	Stereographic projection 70 (for Romania)
SWISS	Swiss projection
TM	Transverse Mercator projection (group of zones)
TM27	Transverse Mercator for the SPC27 system
TM83	Transverse Mercator for the SPC83 system
TMERC	Transverse Mercator projection (simple zone)

The following explains in detail what data the user must specify when setting the parameters in the '*Edit projection parameters'* dialog window:

- for the Alaska Zone 1 (SPC27) projection

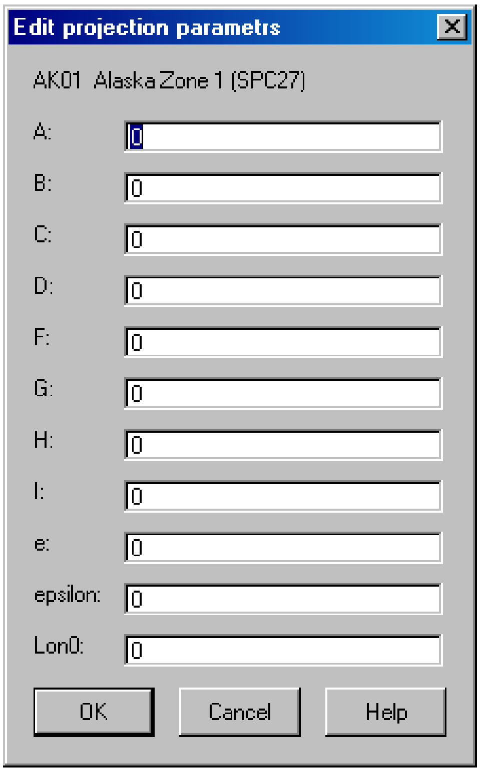


Figure 4-4

Specifications are as follows:

- o ***A, B, C, D, F, G, H, I, e, epsilon*** – constants used for this projection type
- o ***Lon0*** – longitude of the origin of the coordinates for the projection

- for the Alaska Zone 2-9 (SPC27) projection

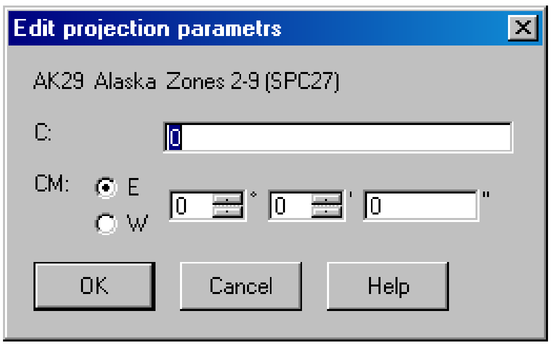


Figure 4-5

Specifications are as follows:

- o ***C*** – false Easting of the origin of coordinates for the projection
- o ***CM*** – longitude of the central meridian

- for the Albers equal-area (orthembadic) conic projection

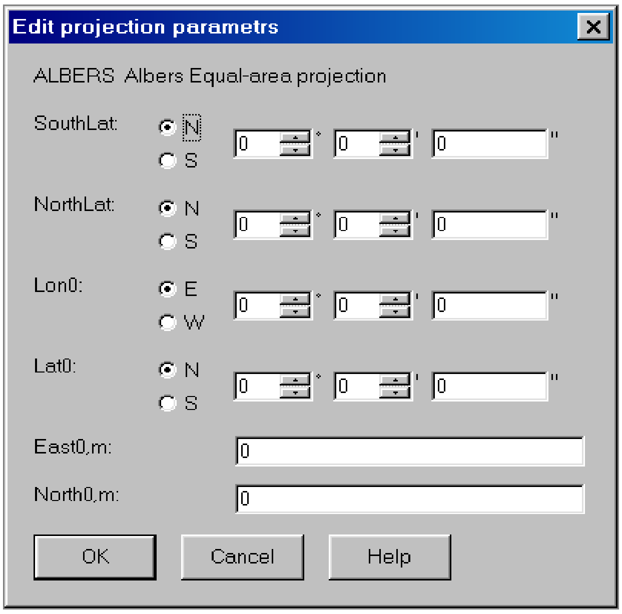


Figure 4-6

Specifications are as follows:

- ***SouthLat*** – latitude of the south standard parallel
- ***NorthLat*** – latitude of the north standard parallel
- ***Lon0*** – longitude of the origin of coordinates of the projection
- ***Lat0*** – latitude of the origin of coordinates of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Bonne pseudoconical equal-area projection

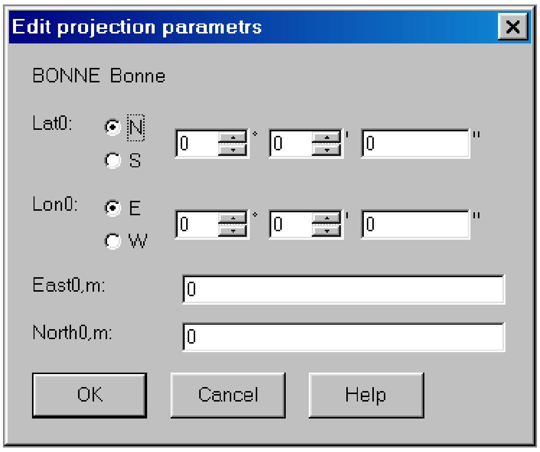


Figure 4-7

Specifications are as follows:

- ***Lat0*** – latitude of the standard parallel
- ***Lon0*** – longitude of the central meridian
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Cassini-Soldner projection (for Malaysia)

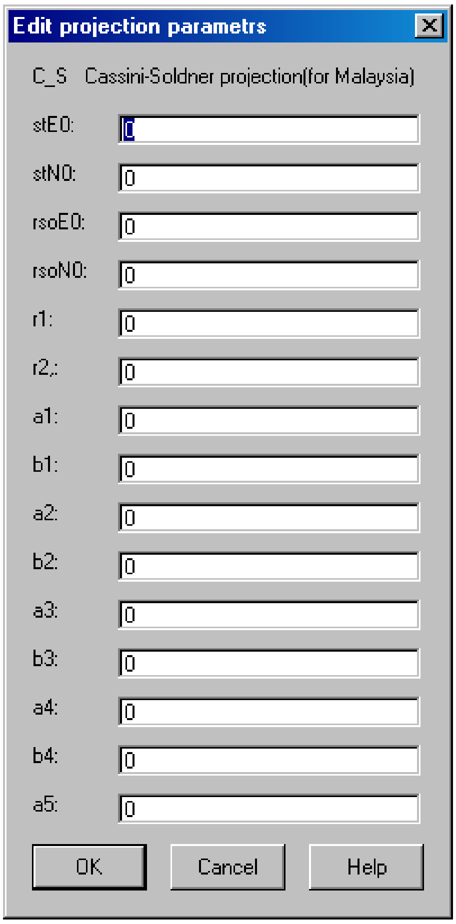


Figure 4-8

Specifications are as follows:

- ***stE0, stN0*** – false coordinates of the state origin of coordinates for *Cassini*
- ***rsoE0, rsoN0*** – false coordinates of the state origin of coordinates for *RSO*
- ***r1, r2, a1, b1, a2, b2, a3, b3, a4, b4, a5, b5*** – transformation parameters

- for the Cassini projection

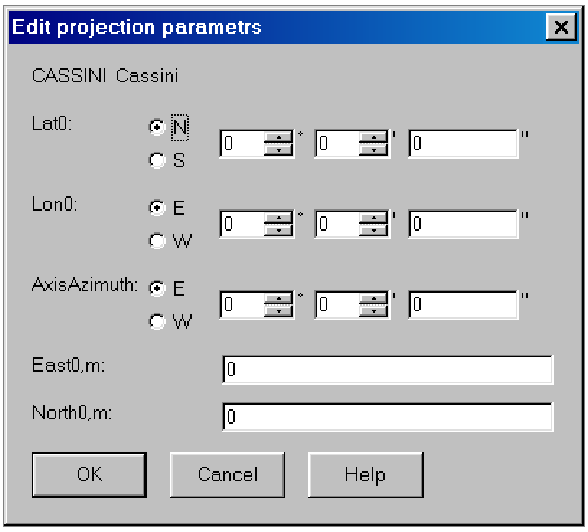


Figure 4-9

The Cassini projection is a cylindrical projection that is neither orthembadic nor conformal.

Specifications are as follows:

- o ***Lat0*** – latitude crossing the central meridian at the origin of plane coordinates of the projection
- o ***Lon0*** – longitude of the central meridian of the projection
- o ***AxisAzimuth*** – azimuth of direction for the scale factor computation
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Cartesian Cartographic projection (Colombia)

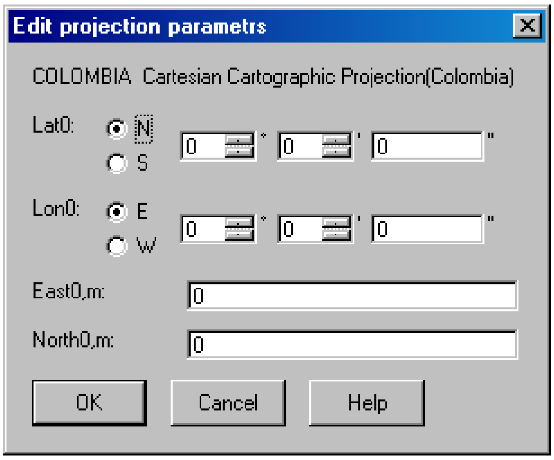


Figure 4-10

Specifications are as follows:

- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Azimuthal Equidistant projection (neither equal-area nor conformal)

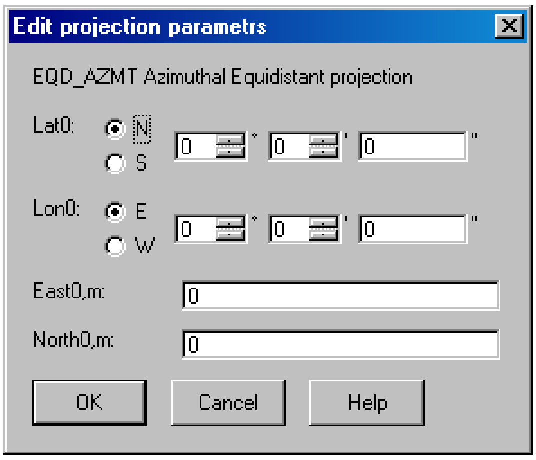


Figure 4-11

Specifications are as follows:

- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Equidistant conic projection with one standard parallel

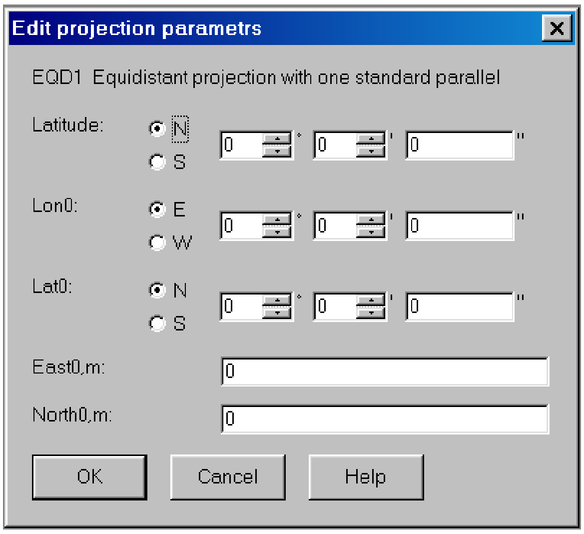


Figure 4-12

Specifications are as follows:

- o ***Latitude*** – latitude of the standard parallel of the projection
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Equidistant conic projection with two standard parallels

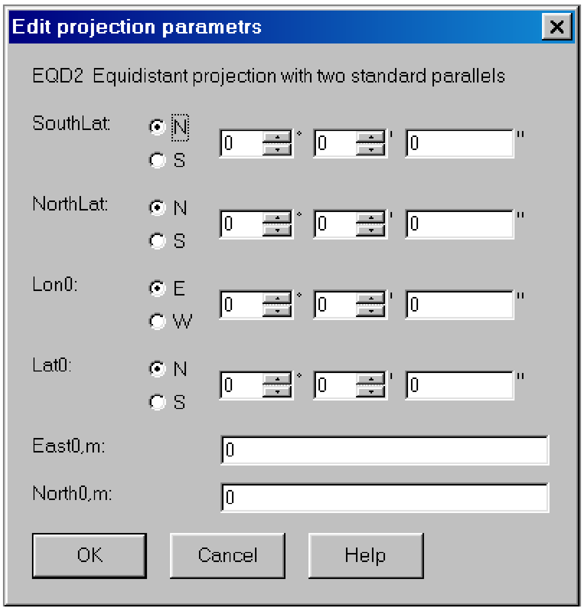


Figure 4-13

Specifications are as follows:

- ***SouthLat*** – latitude of the south standard parallel
- ***NorthLat*** – latitude of the north standard parallel
- ***Lon0*** – longitude of the origin of coordinates of the projection
- ***Lat0*** – latitude of the origin of coordinates of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Lambert conformal conic projection with two standard parallels

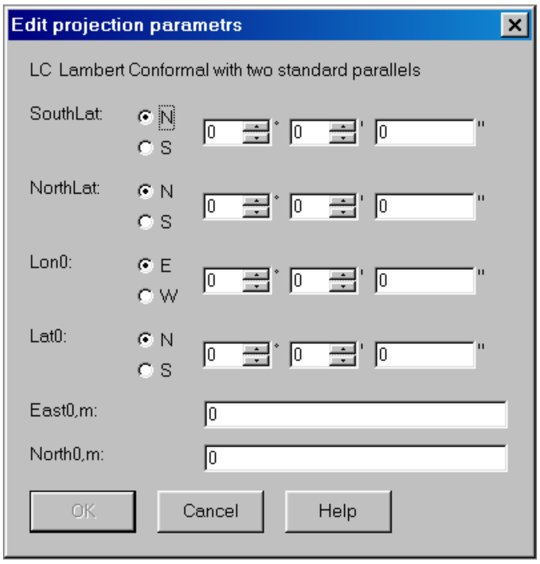


Figure 4-14

Specifications are as follows:

- ***SouthLat*** – latitude of the south standard parallel
- ***NorthLat*** – latitude of the north standard parallel
- ***Lon0*** – longitude of the origin of coordinates of the projection
- ***Lat0*** – latitude of the origin of coordinates of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Lambert conformal conic projection with one standard parallel

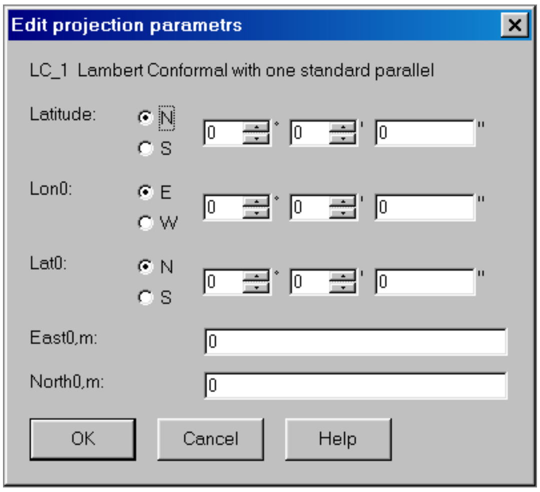


Figure 4-15

Specifications are as follows:

- o ***Latitude*** – latitude of the standard parallel of the projection
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Lambert conformal conic projection for the SPC27 system

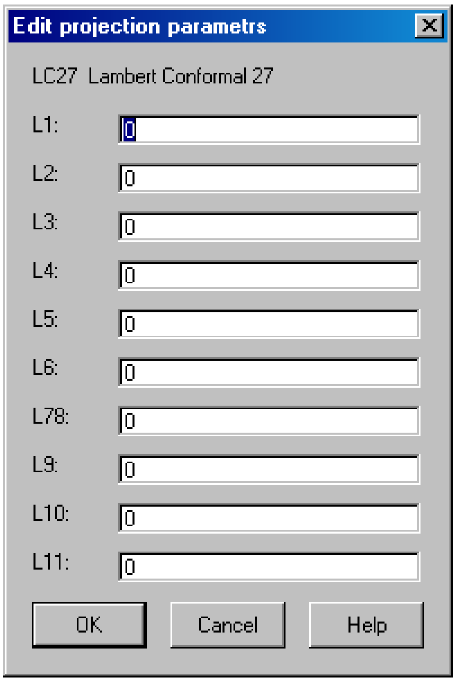


Figure 4-16

Specifications are as follows:

- o ***L1, L2, L3, L4, L5, L6, L78, L9, L10, L11*** – constants for this type of projection

- for the Lambert conformal conic projection for the SPC83 system

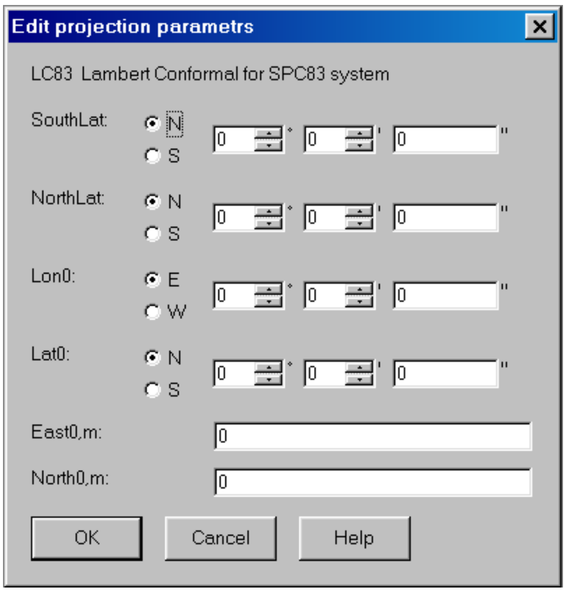


Figure 4-17

Specifications are as follows:

- ***SouthLat*** – latitude of the south standard parallel
- ***NorthLat*** – latitude of the north standard parallel
- ***Lon0*** – longitude of the central meridian
- ***Lat0*** – latitude of the origin of coordinates of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Mercator conformal cylindrical projection

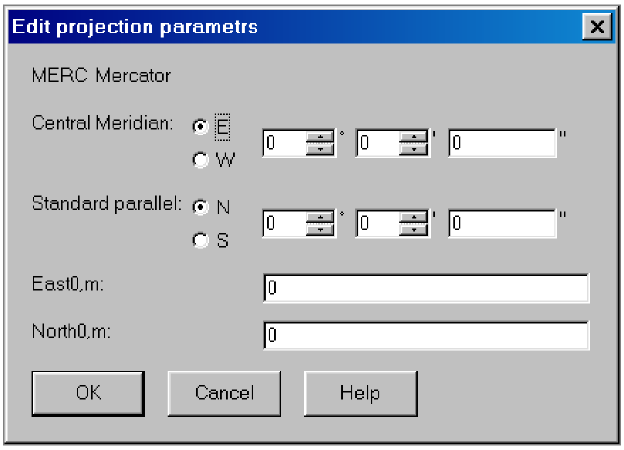


Figure 4-18

Specifications are as follows:

- ***Central Meridian*** – longitude of the central meridian of the projection
- ***Standard parallel*** – latitude of the standard parallel of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Oblique Mercator conformal cylindrical projection

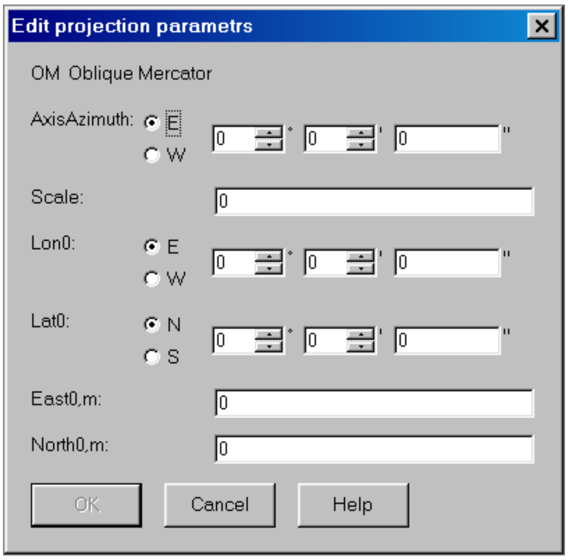


Figure 4-19

Specifications are as follows:

- ***Axis Azimuth*** – azimuth of the central line of the projection
- ***Scale*** – scale factor along the central line of the projection
- ***Lon0*** – longitude of the central point of the projection
- ***Lat0*** – latitude of the central point of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Oblique Mercator conformal cylindrical projection (two points)

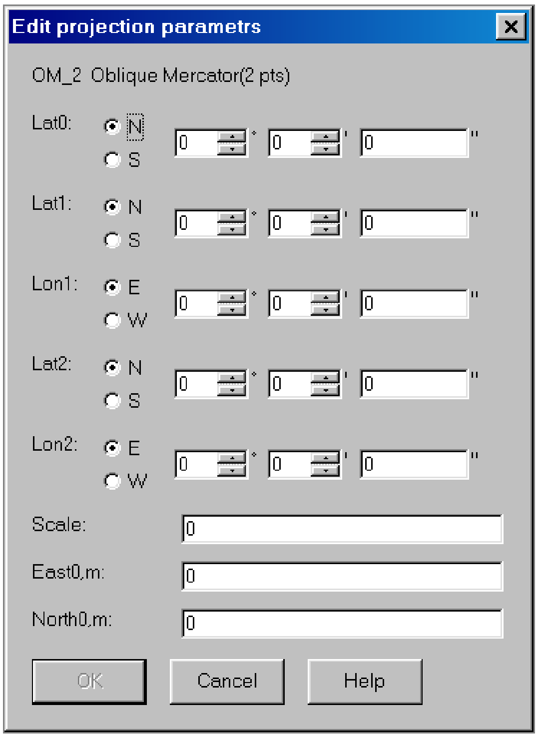


Figure 4-20

The central line of the projection passes through the two specified points. Specifications are as follows:

- ***Lat0*** – latitude of the origin of coordinates of the projection
- ***Lat1*** – latitude of the first point on the central line of the projection
- ***Lon1*** – longitude of the first point on the central line of the projection
- ***Lat2*** – latitude of the second point on the central line of the projection
- ***Lon2*** – longitude of the second point on the central line of the projection
- ***Scale*** – scale factor on the central line of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Oblique Mercator conformal cylindrical projection for SPC83

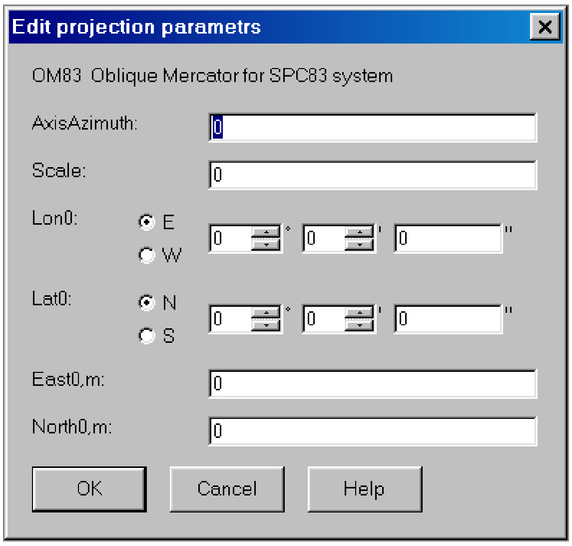


Figure 4-21

Specifications are as follows:

- o ***Axis Azimuth*** – azimuth of the central line
- o ***Scale*** – scale factor on the central line
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Rectified Skew Orthomorphic projection (for Malaysia)

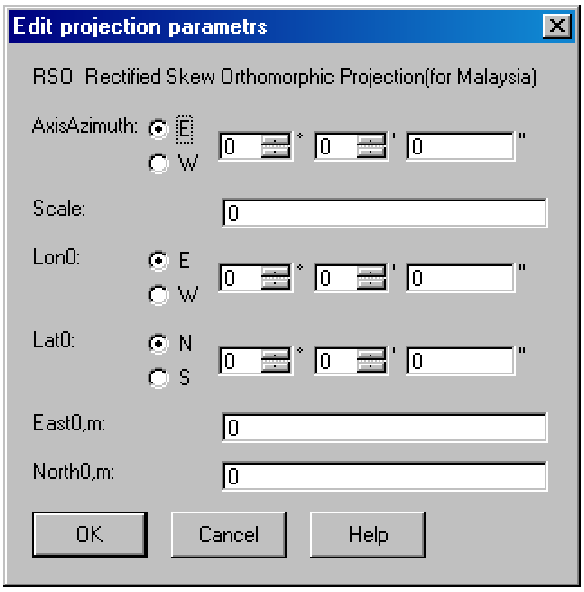


Figure 4-22

The Malaysia Rectified Skew Orthomorphic projection is in fact similar to the Oblique Mercator projection with a rotation applied to it.

Specifications are as follows:

- o ***Axis Azimuth*** – azimuth of the initial line of the projection
- o ***Scale*** – scale factor at the origin of coordinates of the projection
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Sinusoidal pseudo-cylindrical equal-area projection

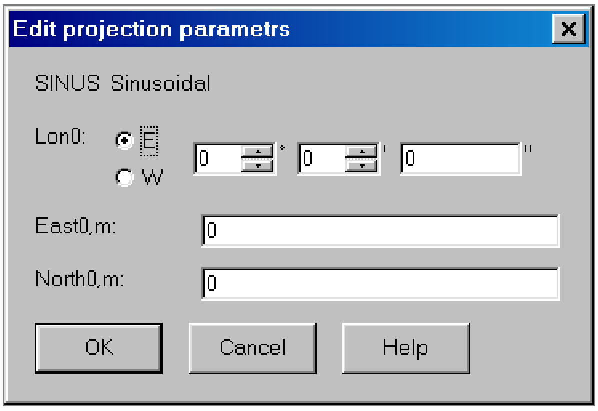


Figure 4-23

Specifications are as follows:

- o ***Lon0*** - longitude of the central meridian of the projection
- o ***East0*** – false Easting of the origin of coordinates of the projection
- o ***North0*** – false Northing of the origin of coordinates of the projection

- for the Stereographic conformal azimuthal projection

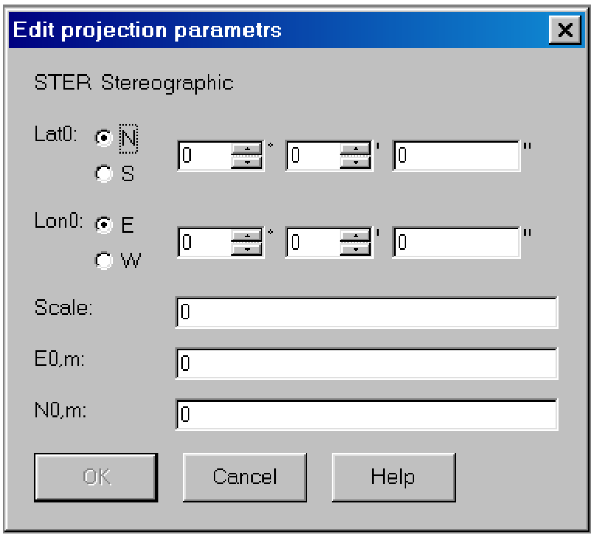


Figure 4-24

Specifications are as follows:

- o ***Lat0*** – latitude of the standard parallel of the projection
- o ***Lon0*** – longitude of the central meridian of the projection
- o ***Scale*** – scale factor at the origin of coordinates of the projection
- o ***E0*** – false Easting of the origin of coordinates of the projection
- o ***N0*** – false Northing of the origin of coordinates of the projection

- for the Stereographic conformal azimuthal projection 70 (for Romania)

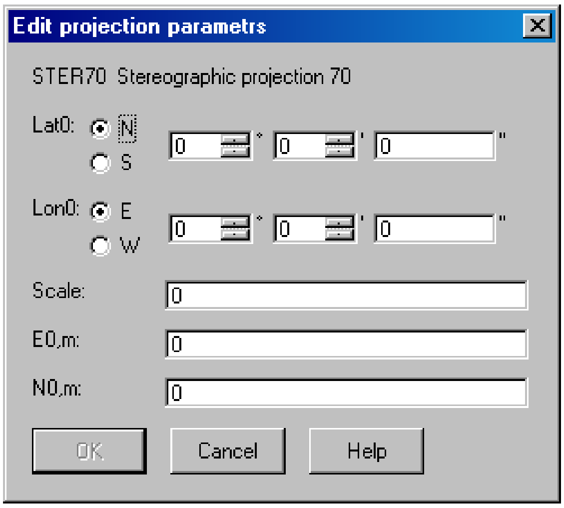


Figure 4-25

Specifications are as follows:

- o ***Lat0*** – latitude of the origin of coordinates of the projection
- o ***Lon0*** – longitude of the origin of coordinates of the projection
- o ***Scale*** – scale factor at the origin of coordinates of the projection
- o ***E0*** – false Easting of the origin of coordinates of the projection
- o ***N0*** – false Northing of the origin of coordinates of the projection

- for the Swiss projection

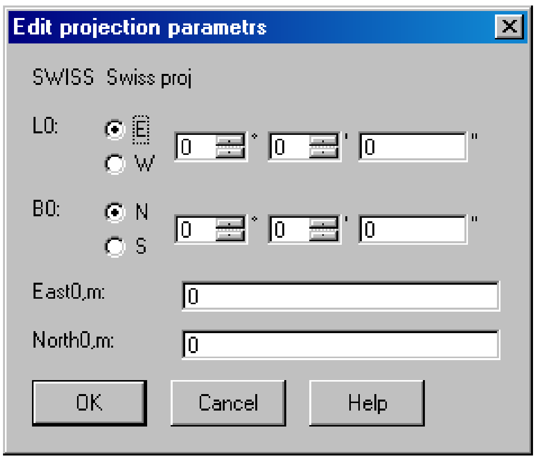


Figure 4-26

Specifications are as follows:

- ***L0*** – longitude of the origin of coordinates of the projection
- ***B0*** – latitude of the origin of coordinates of the projection
- ***East0, North0*** – false coordinates (Easting, Northing) of the origin of coordinates of the projection

* for theTransverse Mercator conformal cylindrical projection (a group of zones)

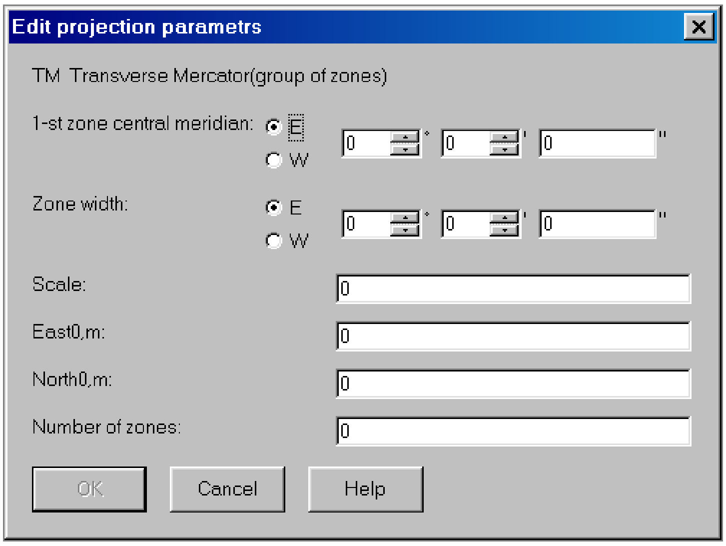


Figure 4-27

Specifications are as follows:

- ***1-st zone central meridian*** – longitude of the central meridian of the first zone
- ***Zone width*** – longitude width of a zone
- ***Scale*** – scale factor on the central meridian of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection
- ***Number of zones*** – number of zones used in the projection

* for the Transverse Mercator conformal cylindrical projection for SPC27

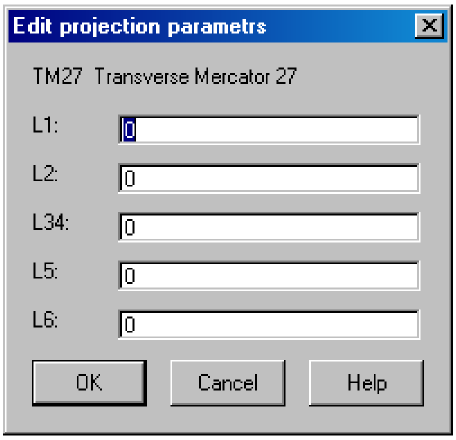


Figure 4-28

Specifications are as follows:

- ***L1, L2, L34, L5, L6*** – constants for this type of projection

- for the Transverse Mercator conformal cylindrical projection for SPC83

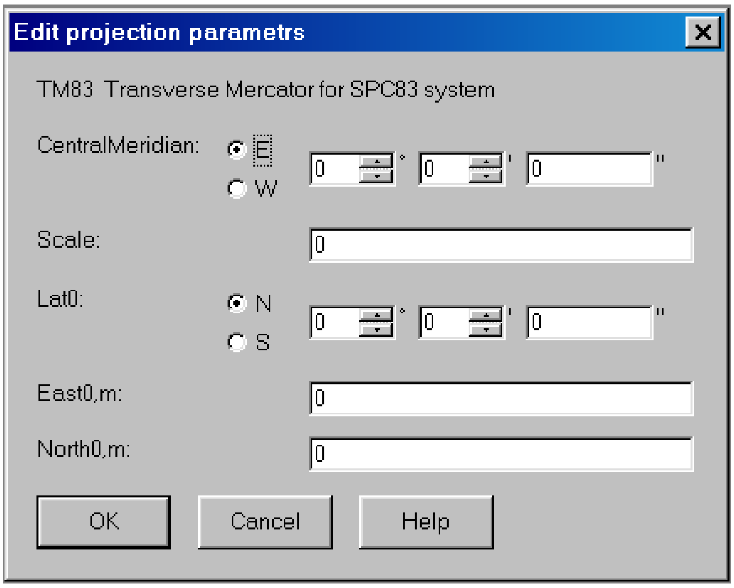


Figure 4-29

Specifications are as follows:

- ***Central Meridian*** – longitude of the central meridian of a zone
- ***Scale*** – scale factor on the central meridian
- ***Lat0*** – latitude of the origin of coordinates of the projection
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

- for the Transverse Mercator conformal cylindrical projection (a simple zone)

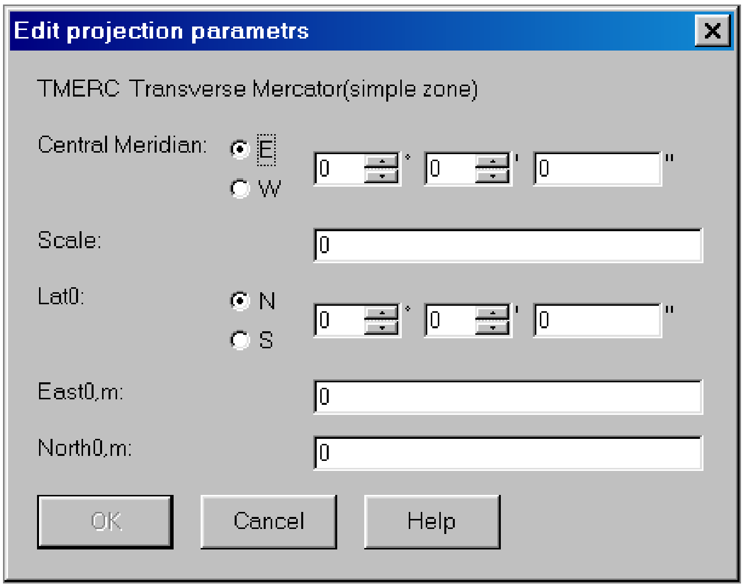


Figure 4-30

Specifications are as follows:

- ***Central Meridian*** – longitude of the central meridian of the projection
- ***Scale*** – scale factor at the central meridian of the projection
- ***Lat0*** – latitude crossing the central meridian at the origin of plane coordinates the standard parallel of the projection (it is usually the Equator)
- ***East0*** – false Easting of the origin of coordinates of the projection
- ***North0*** – false Northing of the origin of coordinates of the projection

4.2. How to view a pre-defined grid system

Note that the actual title[1] of the ***'View/Edit'*** button will depend on whether a pre-defined or user-defined grid system has been selected.

If a pre-defined grid system has been selected, the button will have the title ***'View…'***.

Pressing this button will invoke the following dialog window (see Figure 4-31):

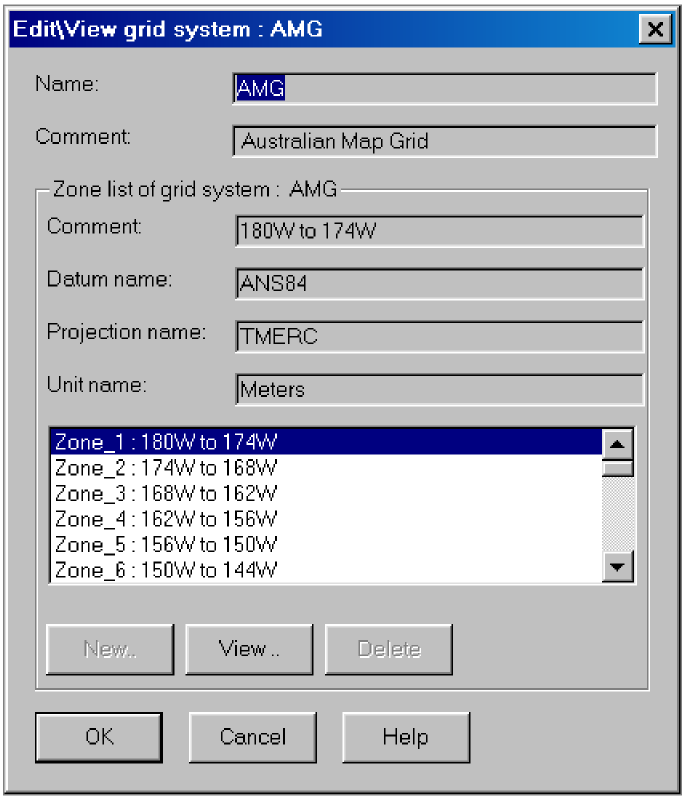


Figure 4-31

This window will provide the user with the following general information about the selected grid system:

- Grid system's name (identificator)
- Comment. (This optional parameter is normally used as the grid system's long name).

The parameters shown under the '*Zone list of grid system'* caption provide a detailed description of the selected zone, specifically:

- Comment. (This optional parameter is often used as the zone's long name).
- Datum's name;
- Projection's name;
- Unit of measurement
- A list of zones existing for the given grid system.

Select the desired zone from the listbox and press the ***'View...'*** button to get more information on this zone (see Figure 4-32):

[1]) either VIEW or EDIT

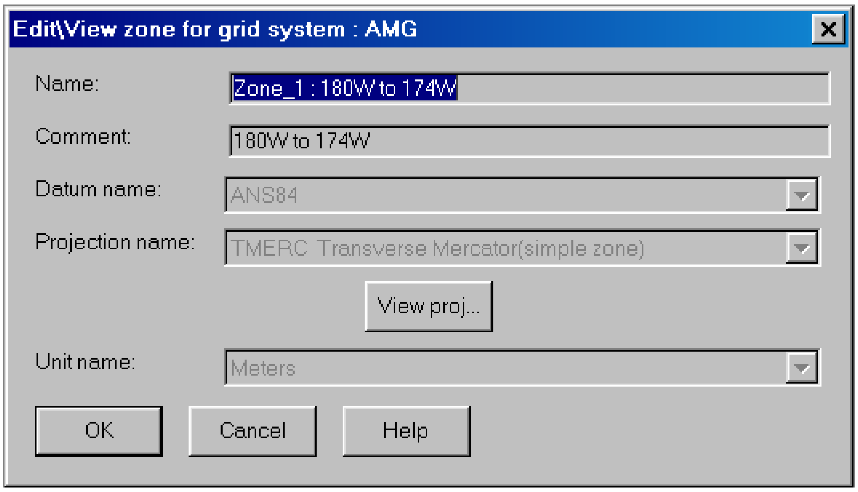


Figure 4-32

Next, press the ***'View proj…'*** button to see the projection parameters in detail (see Figure 4-33):

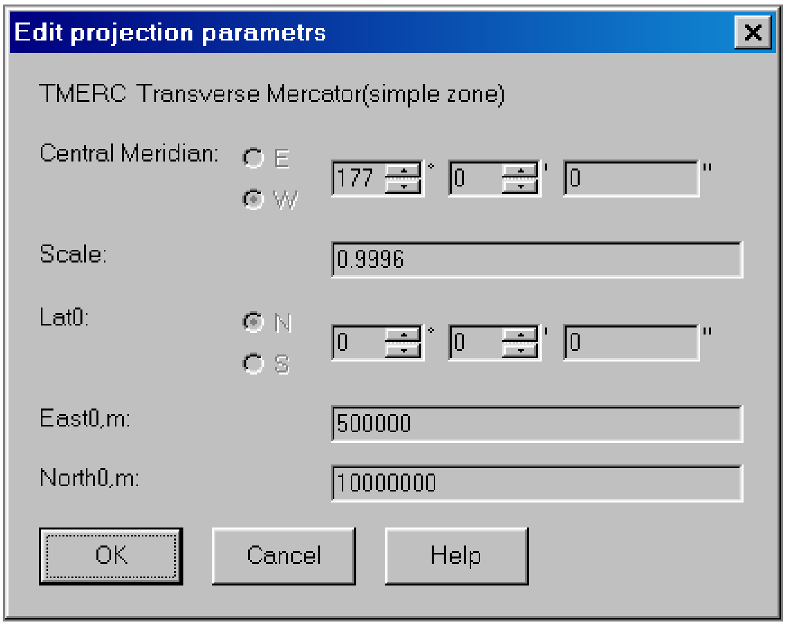


Figure 4-33

4.3. How to edit a user-defined grid system

As mentioned before, the name of the ***'Edit/View'*** button will actually depend on whether a pre-defined or user-defined grid system has been selected. If a user-defined system has been selected, the button will have the title ***'Edit…'***.

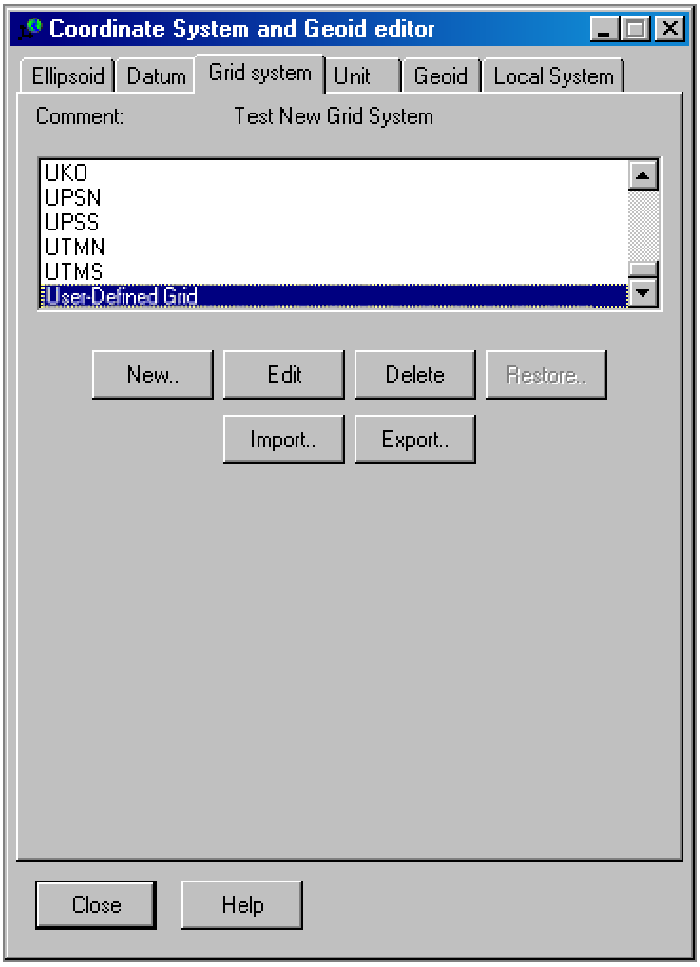


Figure 4-34

Pressing this button will invoke the '*Edit/View*' dialog window (see Figure 4-35, in this example we use a user-defined grid system called ***User-Defined Grid***):

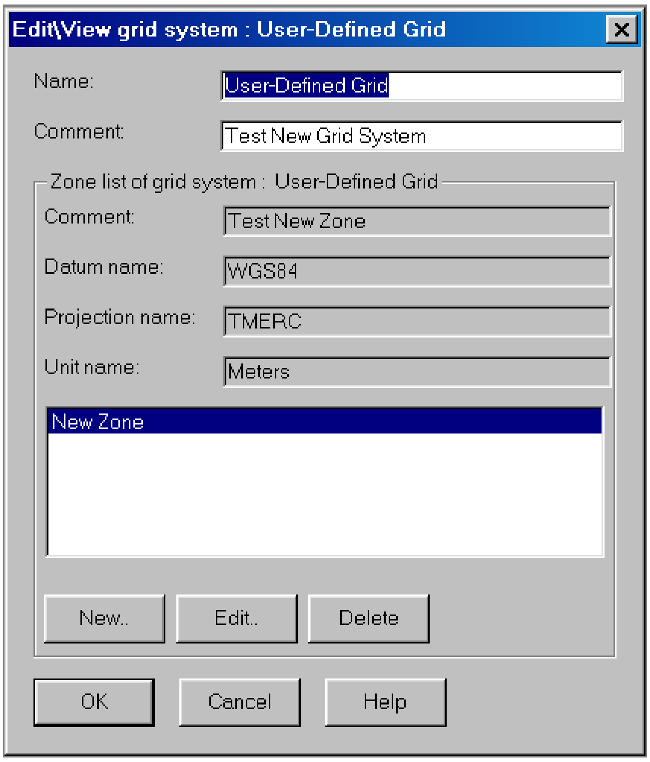


Figure 4-35

In this dialog window, the user may rename the user-defined grid system and/or update the comment.

To edit a zone's parameters, which are displayed in the '*Zone list of grid system'* group box, select this zone from the listbox and press the ***'Edit…'*** button. A dialog window will be opened as shown in Figure 4-36:

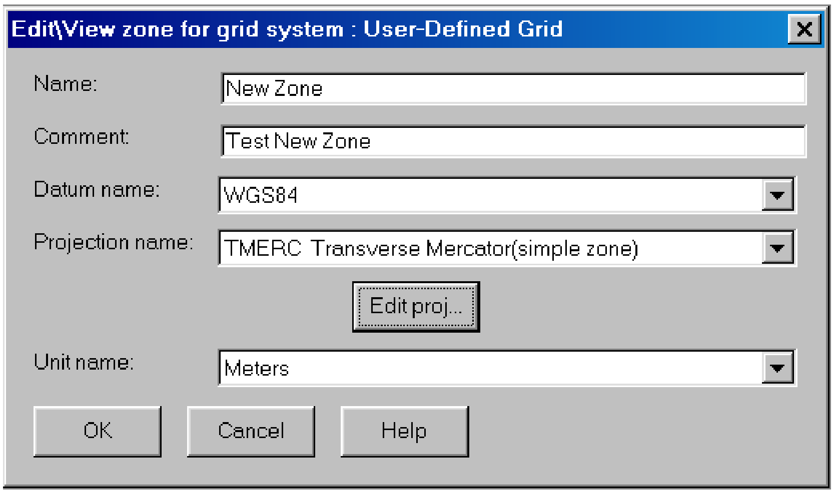


Figure 4-36

To update the zone's settings, press the ***'Edit proj...'*** button. The '*Edit projection parameters'* dialog window will be opened as shown in Figure 4-37:

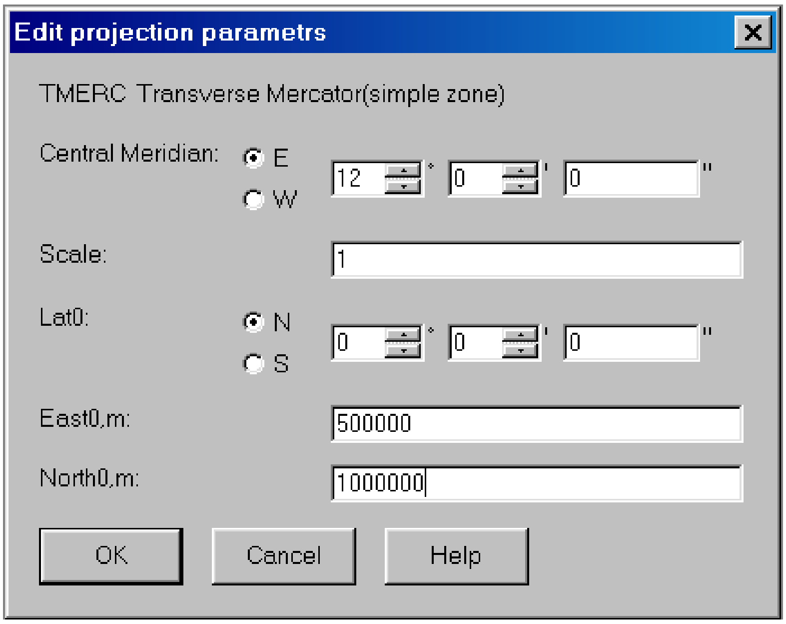


Figure 4-37

The ***'Delete'*** button allows the user to delete the selected zone. Once the ***'Delete'*** button is pressed, the following prompt will appear:

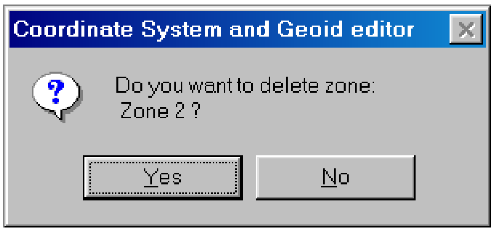


Figure 4-38

The ***'New…'*** button is used to add a new zone to the existing ones (it holds only for the user-defined grid systems). If the ***'New…'*** button is pressed, the following dialog box will appear:

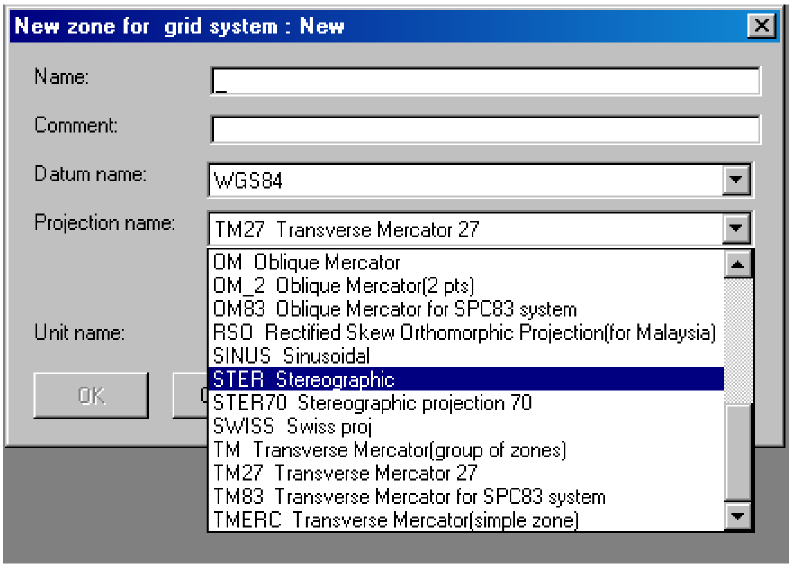


Figure 4-39

The user must enter:

- o the zone's name,
- o a comment (i.e. the zone's long name)
- o the datum's name, and
- o the unit of measurement.

Note that the default settings are '*WGS84*', '*Transverse Mercator*' and '*meters*'.

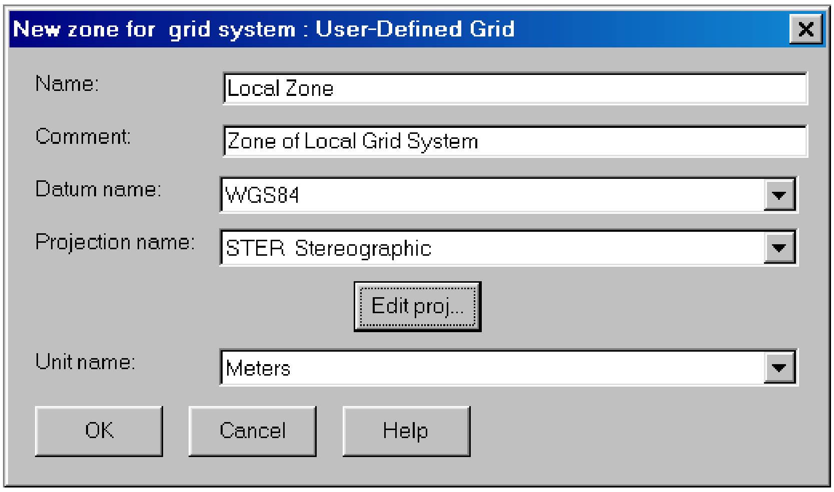


Figure 4-40

Finally, the user may want to update the settings existing for the selected projection type. To do this, the user must press the ***'Edit proj...'*** to open the '*Edit projection parameters*' dialog box as shown in Figure 4-41 for the stereographic projection:

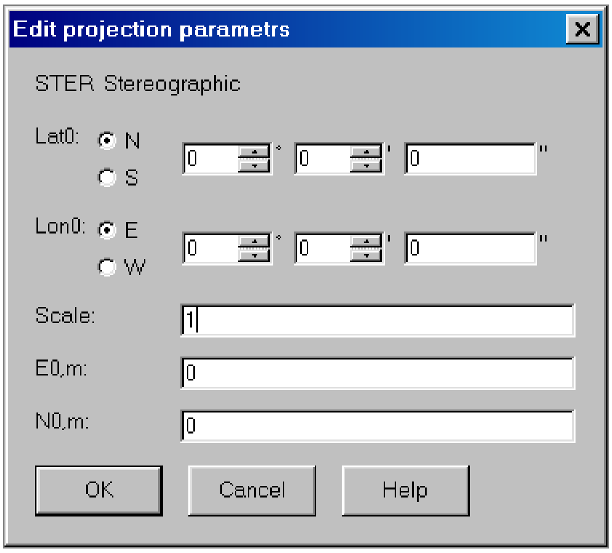


Figure 4-41

4.4. How to delete a user-defined or hide a pre-defined grid system

The '***Delete'*** button is used to delete user-defined or hide pre-defined grid systems.

If a user-defined grid system is selected and the ***'Delete'*** button is pressed, the following prompt will appear:

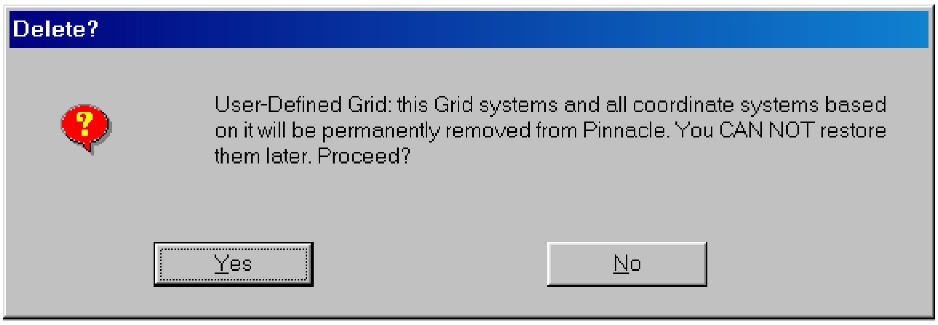


Figure 4-42

Note that once the user presses the ***'Yes'*** button, not only will the selected user-defined grid system be permanently removed from the database but also all the coordinate systems referenced to this grid system.

The user may not delete a pre-defined grid system. However, the user can hide one or more than one pre-defined grid system when Pinnacle listing these grid systems in corresponding dialog windows. To do this, the user must highlight the desired grid system(s) in the listbox as shown in Figure 4-43.

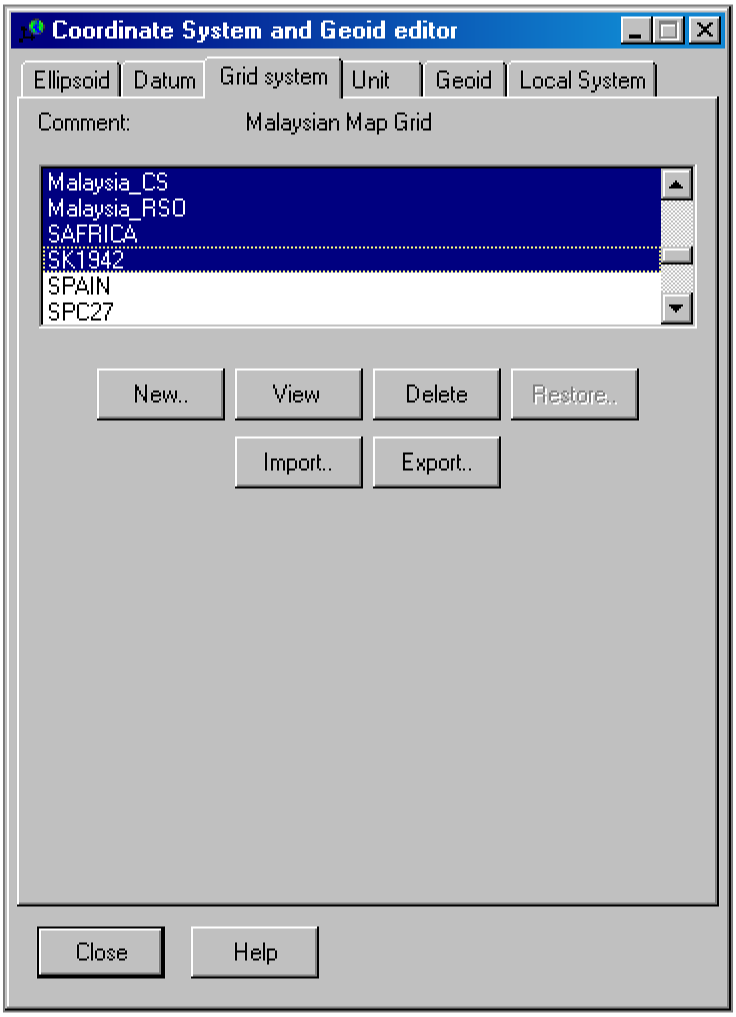


Figure 4-43

and then press the ***'Delete'*** button. The following prompt will pop up:

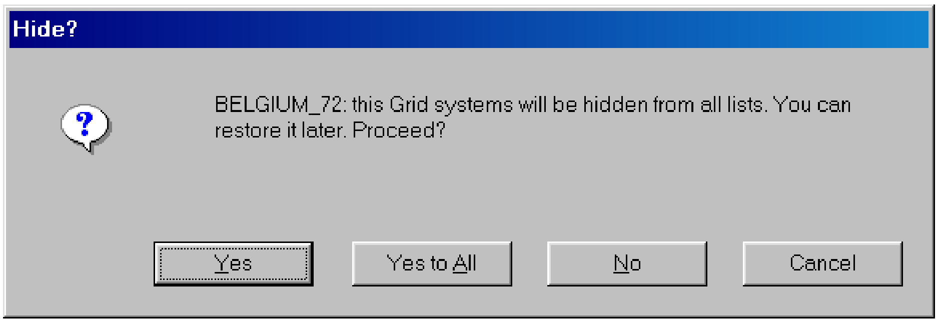


Figure 4-44

Note that the hidden pre-defined grid systems can be restored (unhidden) later.

4.5. How to restore a hidden pre-defined grid system

The ***'Restore…'*** button is used to restore one, or more than one, hidden pre-defined grid system. If any hidden pre-defined grid systems exist in Pinnacle, the ***'Restore…'*** button is active (see Figure 4-45):

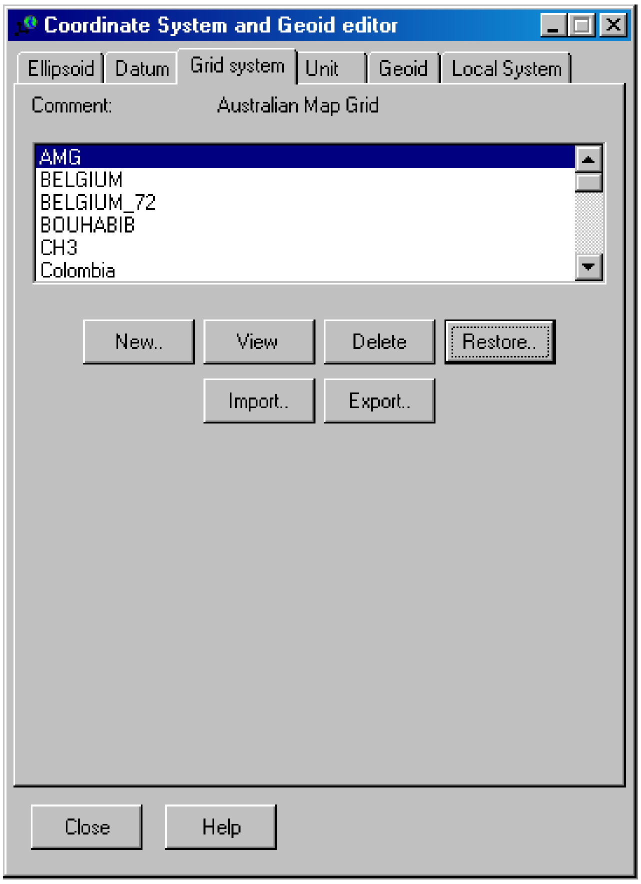


Figure 4-45

Once the ***'Restore…'*** button is pressed, the following dialog window will appear:

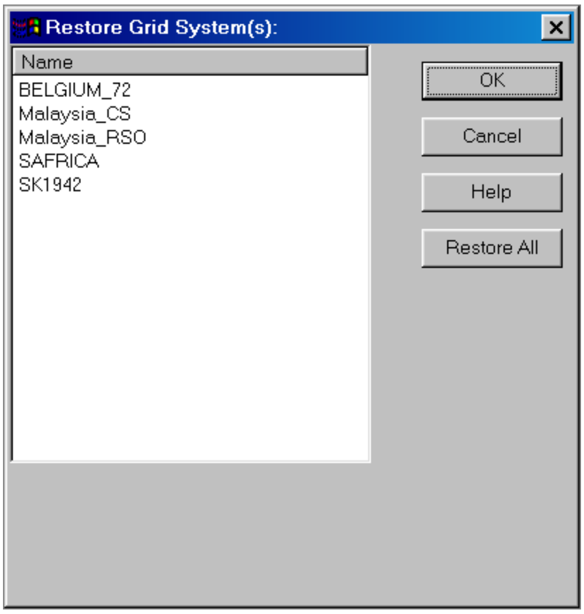


Figure 4-46

The user will need to highlight the desired (hidden) grid system(s) and then press ***'OK'*** to restore them. Pressing the button ***'Restore All'*** will restore all of the hidden grid systems at once.

4.6. How to import a grid system

The ***'Import'*** button allows the user to import a *Pinnacle Grid System* file. Such files, which have the extension ***.jff***, will contain Pinnacle grid systems.

Note that PINNACLE installation includes the file *geosys.jff* that incorporates all of the pre-defined grid systems initially available in Pinnacle.

Pressing the ***'Import'*** button will invoke a standard '*File|Open'* dialog window:

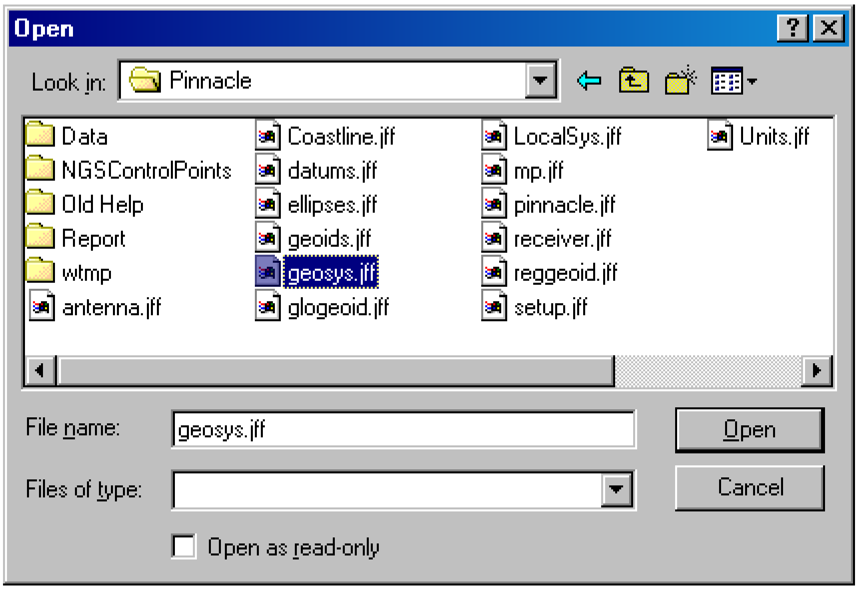


Figure 4-47

4.7. How to export a grid system

The ***'Export…'*** button is used to export datum parameters into a *Pinnacle Grid System* file (such files have the extension ***.jff***).

Pressing this button will invoke a standard *'Save As'* dialog box.

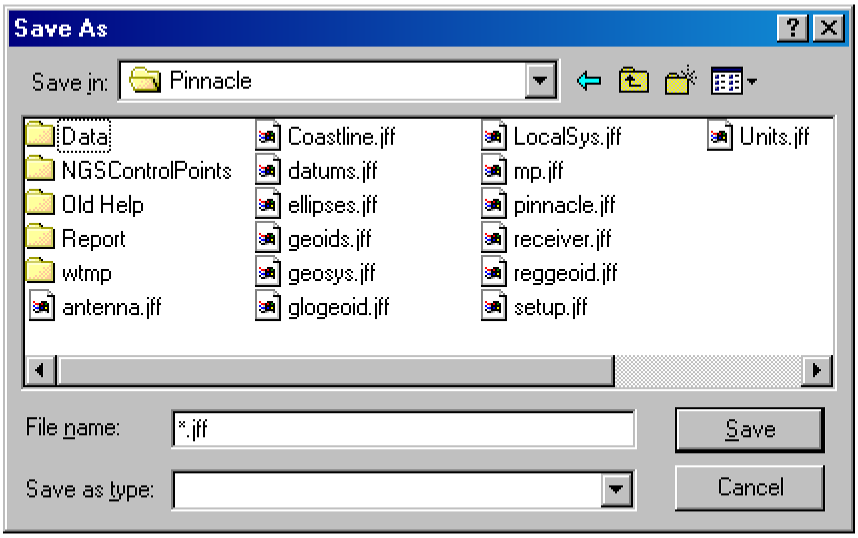


Figure 4-48

This dialog box allows the user to select an existing or create a new *Pinnacle Grid System* file.

If a pre-defined grid system is being exported, the following dialog box will appear:

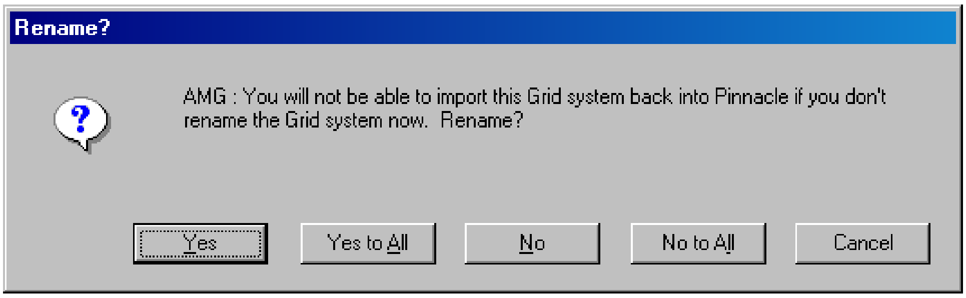


Figure 4-49

If either the *'Yes'* or *'Yes all'* button is pressed, the following dialog box will appear:

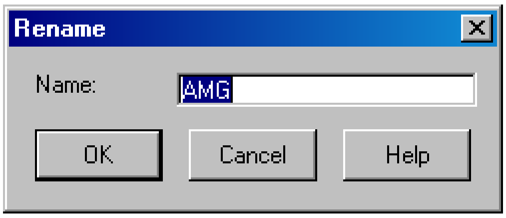


Figure 4-50

This window allows the user to rename the grid system.

5. *Local Systems*

Press Pinnacle's main window's ***System editor*** button and choose the ***Local System*** tab to view, add, edit, delete, import and export the user-defined local systems.

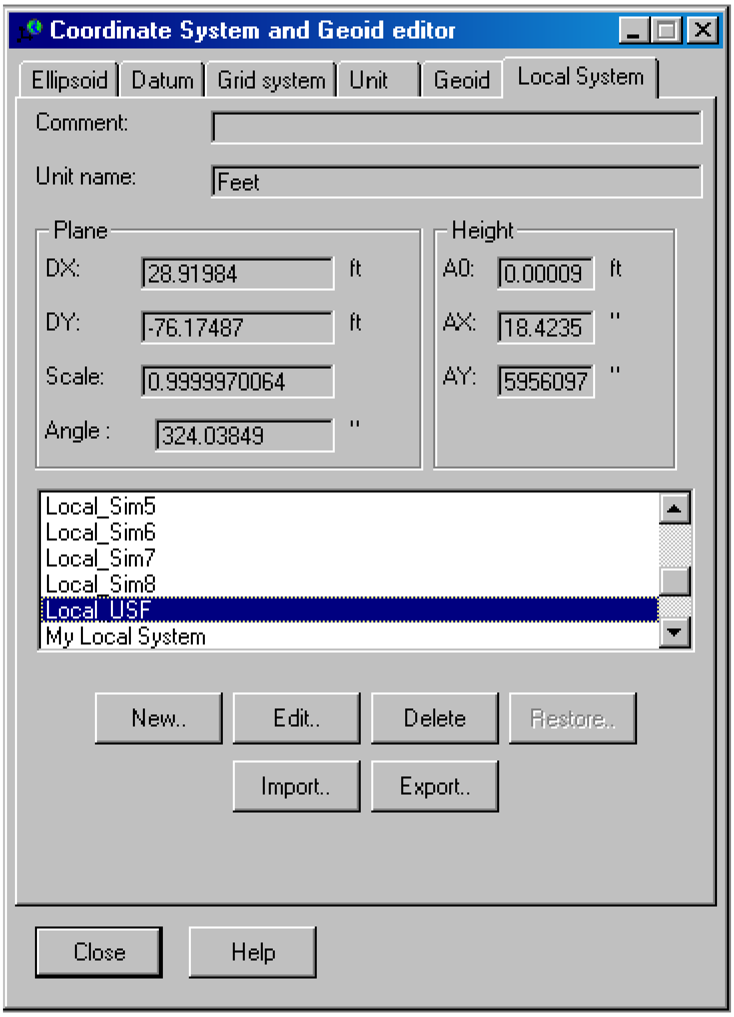


Figure 5-1

This window provides a list of local systems available in Pinnacle (specifically, the local systems' identifications are shown in the window). If a local system is highlighted, its full name (if specified) is displayed in the 'Comment' field. By definition, a local system is determined, along with other features, by its identification, a comment / full name [optional parameter] and the unit of measurement.

The **Local System** option was introduced in Pinnacle to simplify localization jobs performed in construction areas based on GNSS technology/receivers. Localization is generally used to obtain points' coordinates in a ground level coordinate system which *has no connection with any specific geodetic datum*. In this case more than three points are required to solve both horizontal and vertical localization tasks.

In Pinnacle two-dimensional conformal transformations are used for horizontal localization. This kind of transformation is also known as a *four-parameter similarity transformation* (rotation, scale and two translation parameters). In this case, to relate the ellipsoidal geodesic coordinates of GNSS points to their local plane coordinates (obtained with total stations, etc.), an oblique stereographic map projection is used as an intermediate step.

$$\begin{bmatrix} X \\ Y \end{bmatrix}_{Local} = Scale \cdot \begin{bmatrix} \cos(Angle) & -\sin(Angle) \\ \sin(Angle) & \cos(Angle) \end{bmatrix} \cdot \begin{bmatrix} N \\ E \end{bmatrix}_{Stereo} + \begin{bmatrix} DX \\ DY \end{bmatrix}$$

For vertical localization, a three-parameter transformation (one shift and two slopes) is used to convert between the points' ellipsoidal heights, on the one hand, and their elevations in the local height system, on the other hand.

These three parameters are necessary to adequately specify the plane that models the differences between the local geoid and the WGS84 ellipsoid in the given local area:

$$H_{Local} = U + A0 + AX \cdot N + AY \cdot E$$

In Pinnacle you can access a local coordinate system immediately after applying this local system its name.

- The ***'New..'*** button allows the user to create a new local system. If this button is pressed, the following dialog box appears:

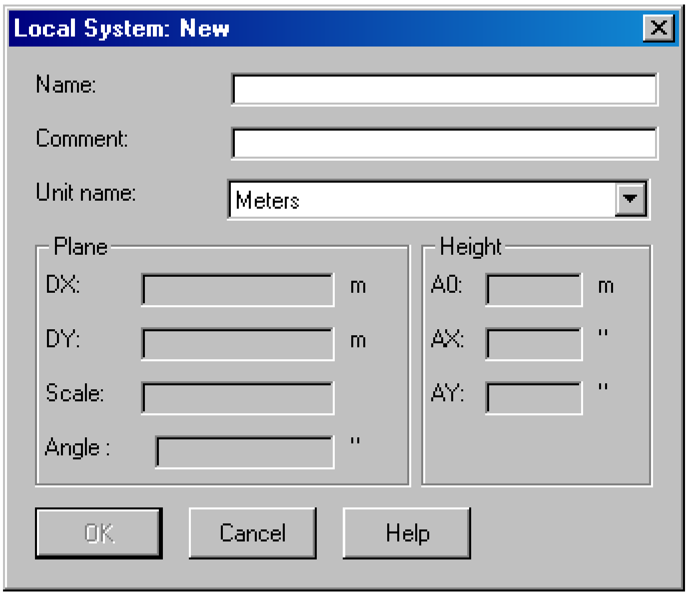


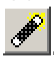
Figure 5-2

Enter the new local system's name and a comment if necessary. Select the desired linear unit of measurement from the *'Unit name:'* pull-down list.

The parameters of the horizontal (*DX, DY, Scale, Angle*) and vertical (*A0, AX, AY*) localization will be obtained later with ***Table Calculator***.

Press the *'OK'* button to enable this new local system.

Note. Also, a new local system can be created when importing a control data list from a text file or after the localization parameters have been determined with ***Table Calculator***.

Another way to create a new local system is specify it when importing raw data with the Wizard . When the raw data import starts, the following dialog window will appear.

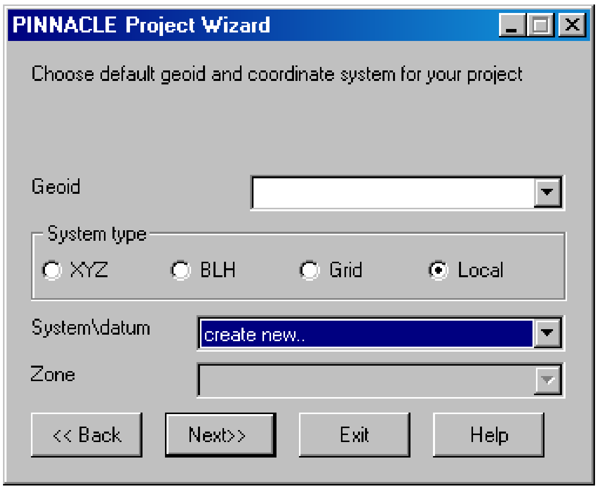


Figure 5-3

After the *'Local'* radio button is chosen and the *'Next>>'* button is pressed, the *"New local System"* dialog window will appear. By default the Wizard will assign the new local system the name of the corresponding network. After that the user can change the default name if required and press *'OK'*.

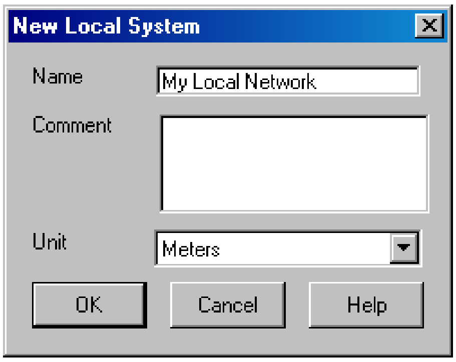


Figure 5-4

From now on the newly created local system will be available throughout Pinnacle.

- The ***'Edit'*** button is used to edit a user-defined local system. After pressing this button the following dialog box appears:

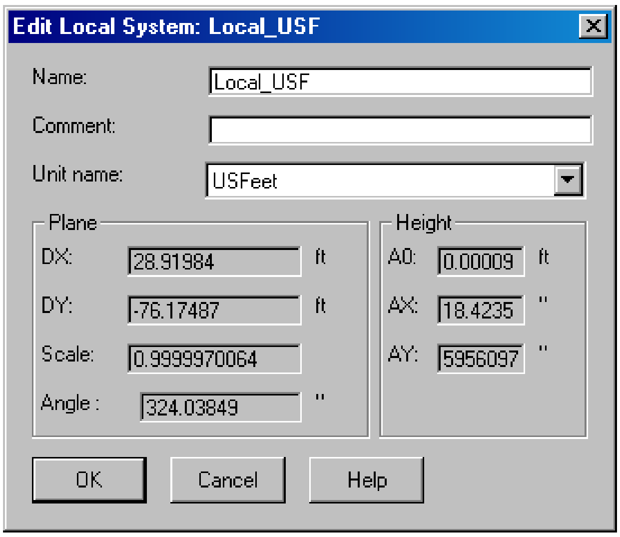


Figure 5-5

You can modify data in the *Name*, *Comment* and *Unit name* fields if necessary.

Note that the parameters of the horizontal (DX, DY, Scale, Angle) and vertical (A0, AX, AY) localization *cannot* be changed in this dialog box.

Press the *'OK'* button to update the selected local system.

- The '***Delete'*** button is used to delete user-defined local systems.

  If a user-defined local system is selected and the ***'Delete'*** button is pressed, the following prompt will appear:

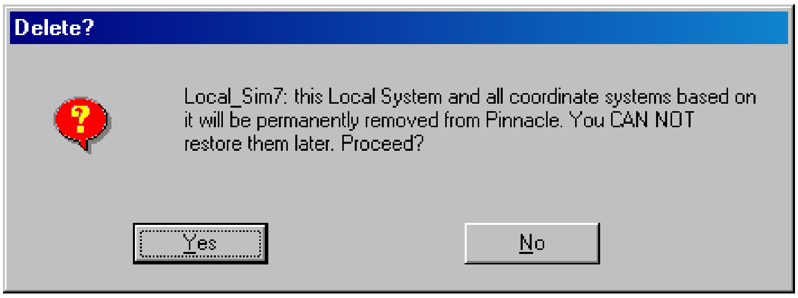


Figure 5-6

  Note that once the user presses the ***'Yes'*** button, the selected user-defined local system will be permanently removed from the database and the user *will not* be able to restore it later.

- The ***'Import…'*** button is used to import a local system to a *Pinnacle Local System* file (such files have the extension ***.jff***). Once pressed, this button will invoke a standard *Open File* dialog box.
- The ***'Export…'*** button is used to export a local system to a *Pinnacle Local System* file (such files have the extension ***.jff***). Once pressed, this button will invoke a standard *Save File* dialog box.

6. *Linear Units of Measurement*

The user must press the '*Coordinate System Editor*' button  on the main window's toolbar and choose the '***Unit'*** tab to:

- View, hide import and export the pre-defined units.
- Add, edit, import, export or delete user-defined units.

PINNACLE installation includes a set of pre-defined units which can be used but not modified or removed from the database.

New user-defined units can be added to the existing ones through the ***'Unit'*** dialog box (by using the ***'New…'*** button).

Note that only the user-defined units may be edited and deleted.

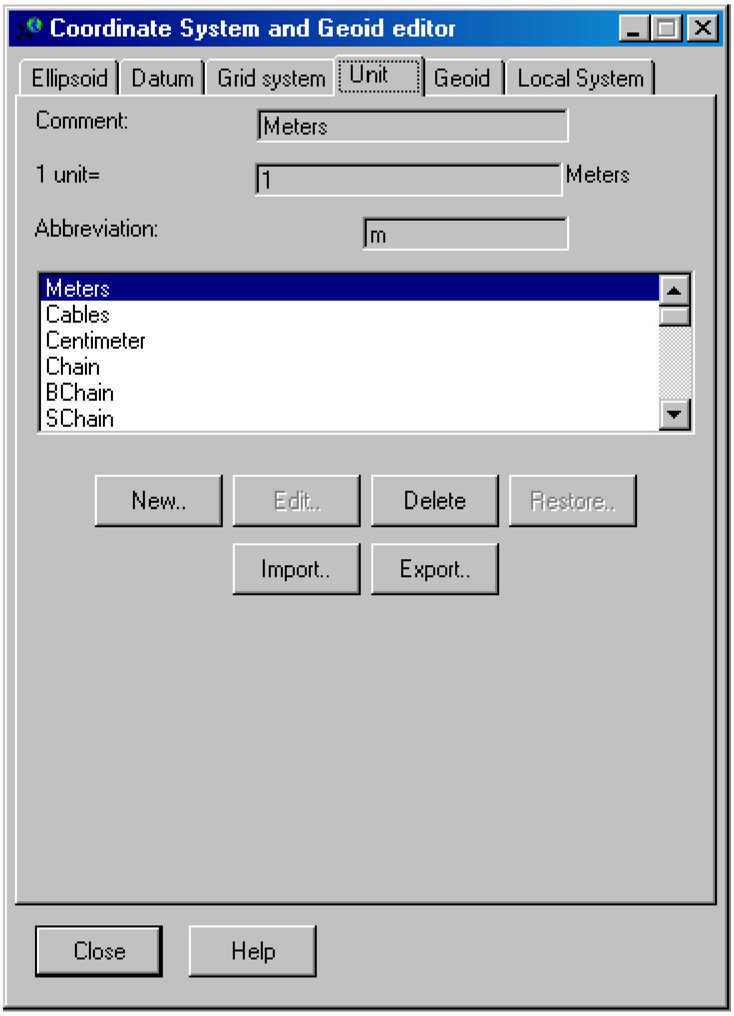


Figure 6-1

The '***Unit'*** tab provides the user with general information about the selected unit, specifically:

- o the unit's long name as specified in the '*Comment'* field;
- o the value of this unit if measured in meters
- o and the unit's abbreviation.

The user can either choose a unit from the listbox (in order to view or edit its parameters) or create a new one.

The following will explain to the reader how the buttons available in this window are used:

- ***'New…'*** button allows the user to create a new unit.

  If this button is pressed, the '*New unit'* dialog box will appear:

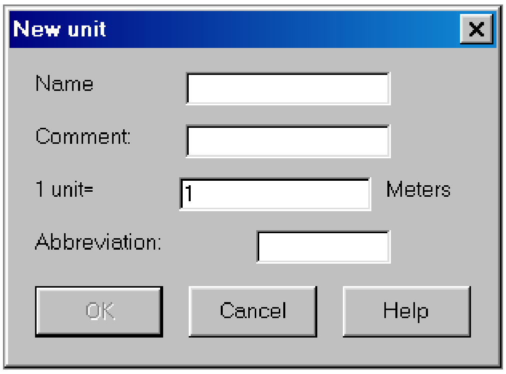


Figure 6-2

  Enter the new unit's name, its long name (this is optional), its value and abbreviation *(not more* then 4 symbols).

  Then press the ***'OK'*** button to add the new unit to the database.

- ***'Edit…'*** button is used to edit a user-defined unit.

  After pressing this button, the '*Edit unit'* dialog window will be opened:

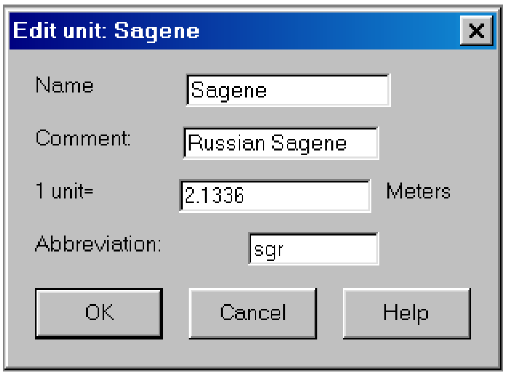


Figure 6-3

  The user can modify some or all of the displayed values, if required.

  Press the ***'OK'*** button to save the updated unit.

- ***'Delete'*** button allows deletion of a user-defined or hiding of a pre-defined unit.

  If a user-defined unit is selected and the ***'Delete'*** button is pressed, the following prompt will pop up:

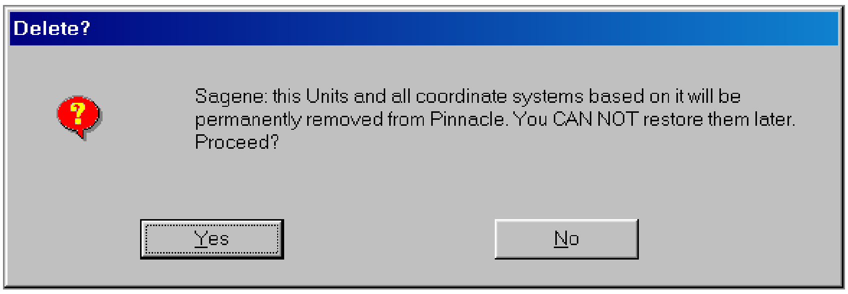


Figure 6-4

Note that once the user presses ***'Yes',*** not only will the selected user-defined unit be permanently removed from Pinnacle but also all of the coordinate systems that are based on this unit.

The user cannot delete a pre-defined unit. The user, however, can hide one or more than one unit available in the pre-defined units' list. To do this, the user must highlight the desired unit(s) in the listbox as shown in Figure 6-5

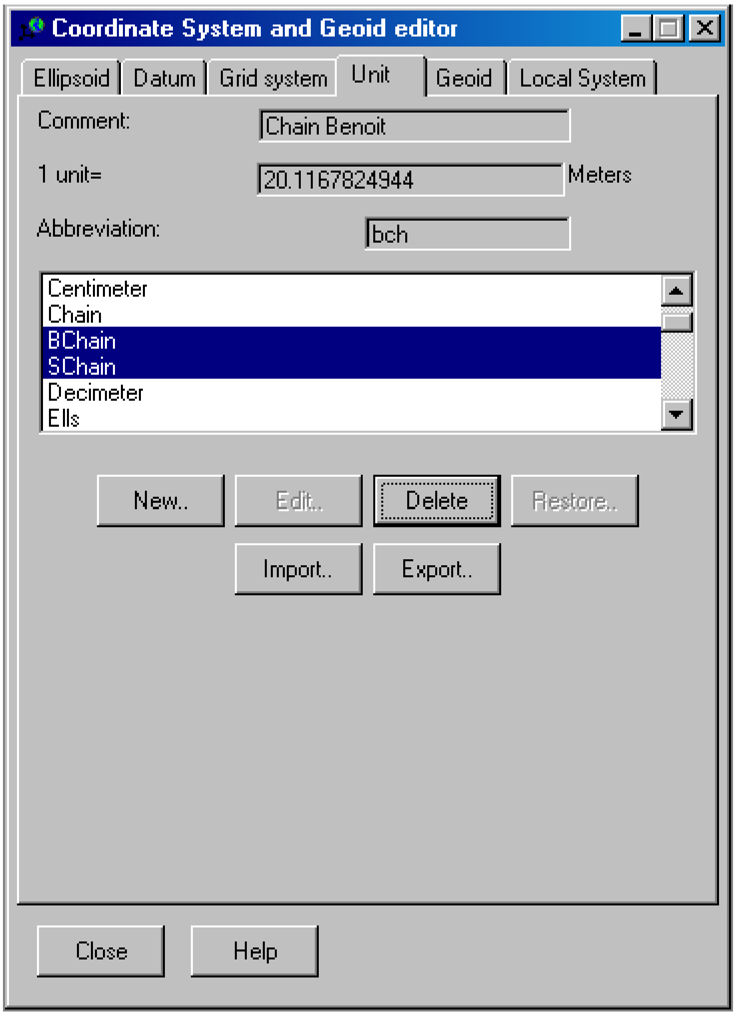


Figure 6-5

and press the ***'Delete'*** button. The following prompt will pop up:

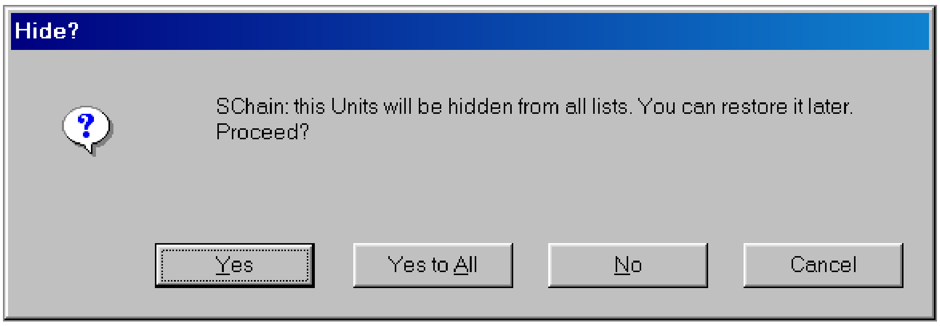


Figure 6-6

Note that all hidden pre-defined units can be restored later if necessary.

- ***'Restore…'*** button is used to restore (unhide) a hidden pre-defined unit.

  If any hidden pre-defined unit(s) exist in Pinnacle, the ***'Restore…'*** button will be active:

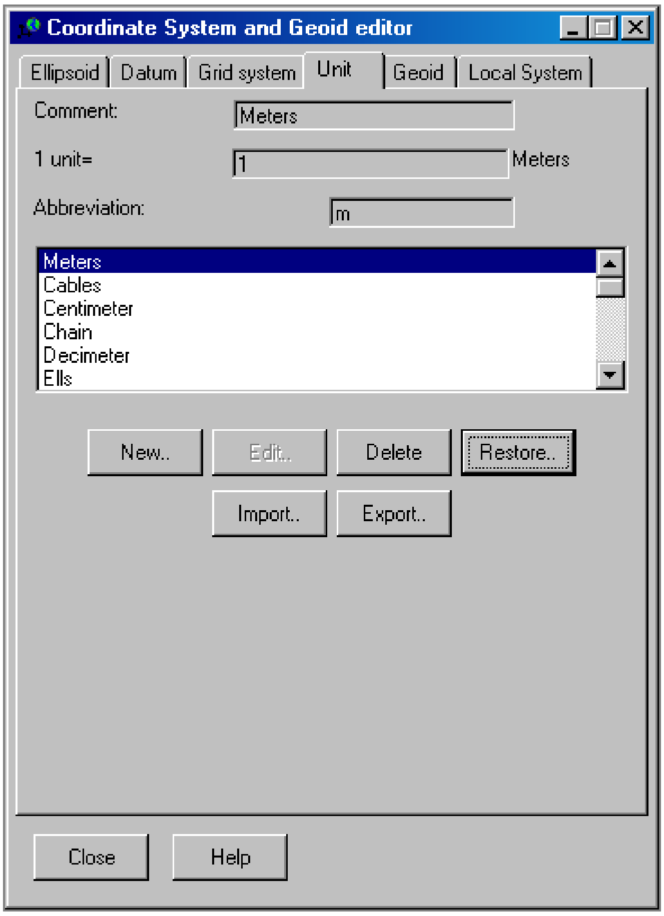


Figure 6-7

If the ***'Restore…'*** button is pressed, the following dialog window will appear:

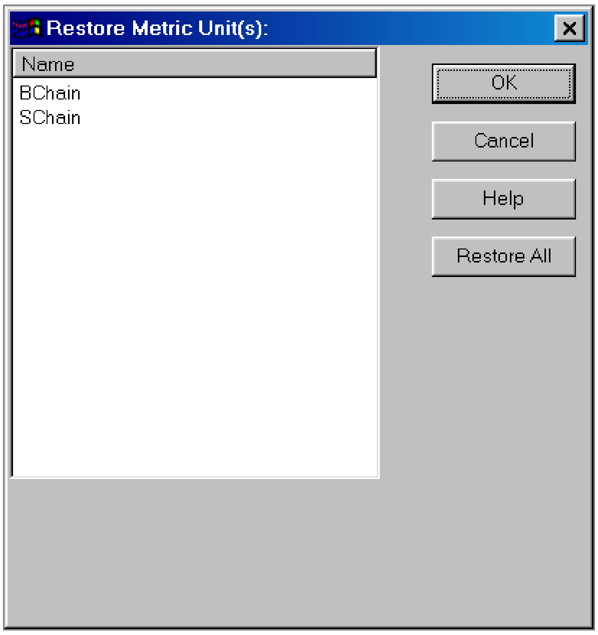


Figure 6-8

The user can highlight the desired unit(s) and press ***'OK'*** to unhide them. Pressing the ***'Restore All'*** button will restore all of the hidden units at once.

- ***'Import'*** button is used to import *Pinnacle Unit* files. Such files, which have the extension ****.jff***, contain Pinnacle's pre-defined units.

Note that PINNACLE installation includes the file *Units.jff* that incorporates all of the pre-defined units initially available in Pinnacle.

Press the ***'Import'*** button to invoke the standard *File|Open* dialog box:

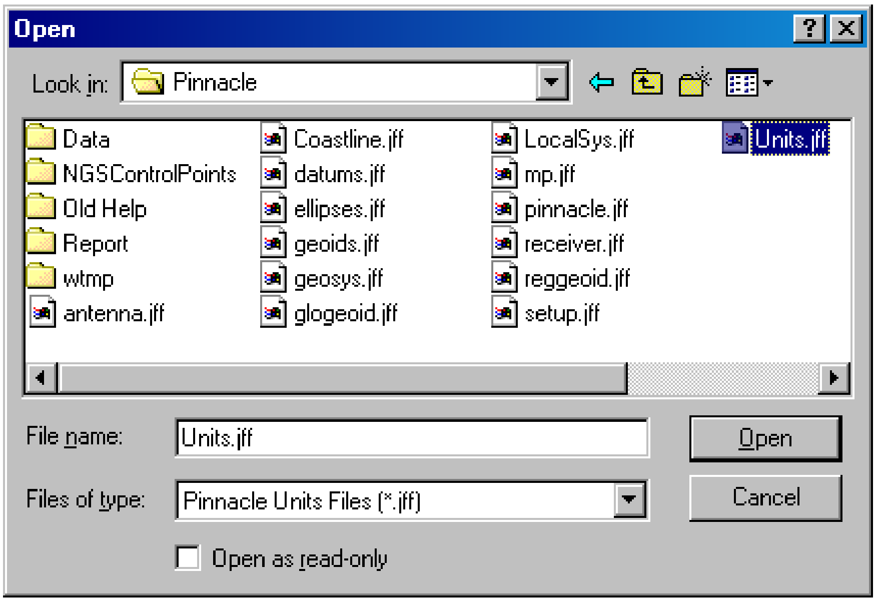


Figure 6-9

- ***'Export…'*** button is used to export units into a *Pinnacle Unit* file (such files have the extension ****.jff***).

Pressing this button will invoke a standard *'Save As'* dialog box.

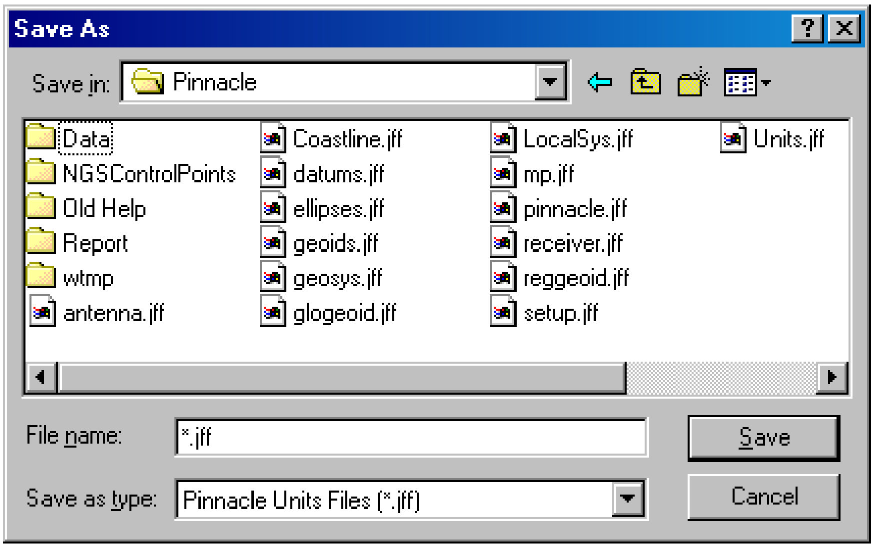


Figure 6-10

This dialog box allows the user to select an existing or create a new *Pinnacle Unit* file.

When a pre-defined unit is being exported, the following dialog box will appear:

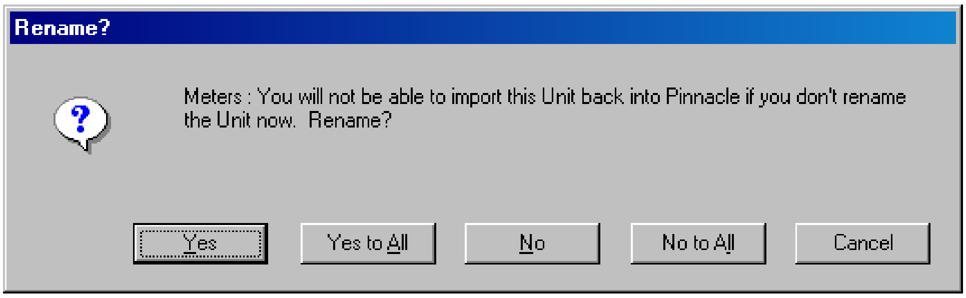


Figure 6-11

If either the *'Yes'* or *'Yes all'* button is pressed, the following dialog box will appear:

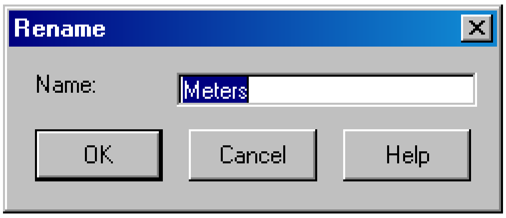


Figure 6-12

This window allows renaming of the unit.

7. *Coordinate Calculator*

Coordinate Calculator is used to transform a point's coordinates from one coordinate system to another.

To activate *Coordinate Calculator*, press the button  on the main window's toolbar. The *Calculator* window will be opened.

Choose the *Calculator* tab to start *Coordinate Calculator*.

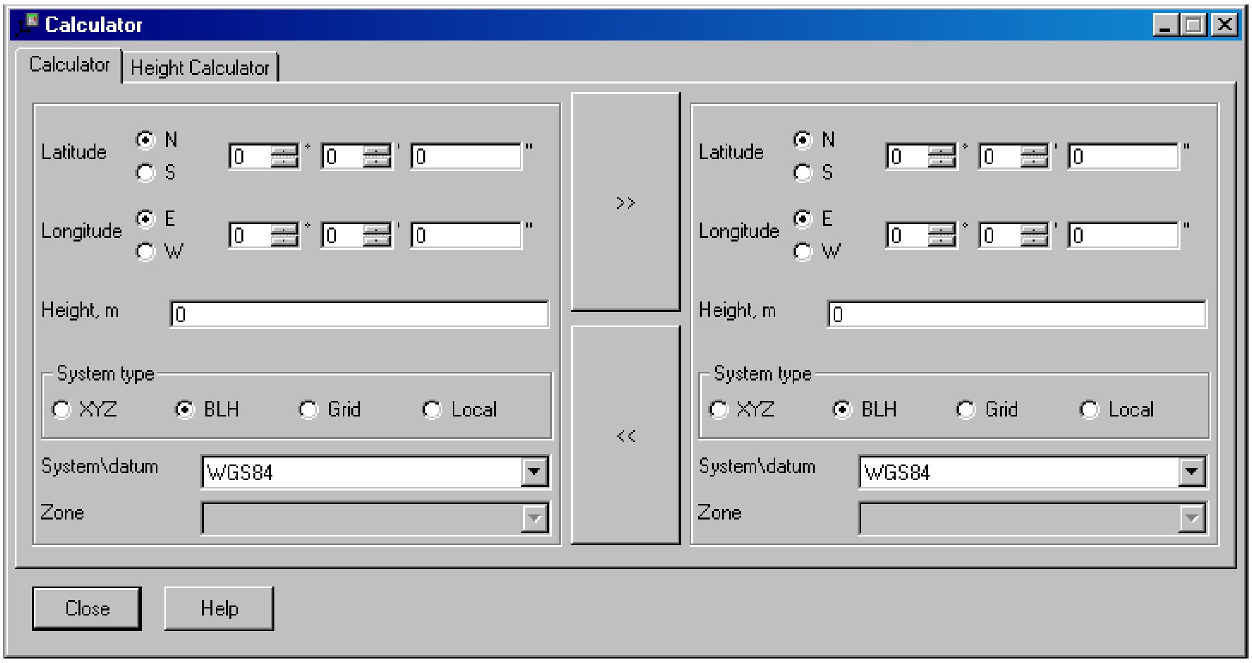


Figure 7-1

The *Calculator* dialog window comprises two equivalent panels. One of these is associated with the *input* coordinate system ("From"); the other - with the output coordinate system ("To").

To transform coordinates, go to either panel and select the desired coordinate type in the '*System type'* radio button group: Cartesian (*"XYZ*"), Geodetic (*"BLH*" - *Latitude, Longitude, Ellipsoidal Height),* Grid *("NEU" - Northing and Easting in a map projection, Optometric Height)* or Local *("NEU" - conventional x, y and height)*.

Note that the initial controls may or may not change in this panel after this. (It will depend on what system type has been selected). In Figure 7-2 , controls on the left-hand panel corresponds to Cartesian coordinates, whereas the controls on the right-hand panel relates to geodetic coordinates:

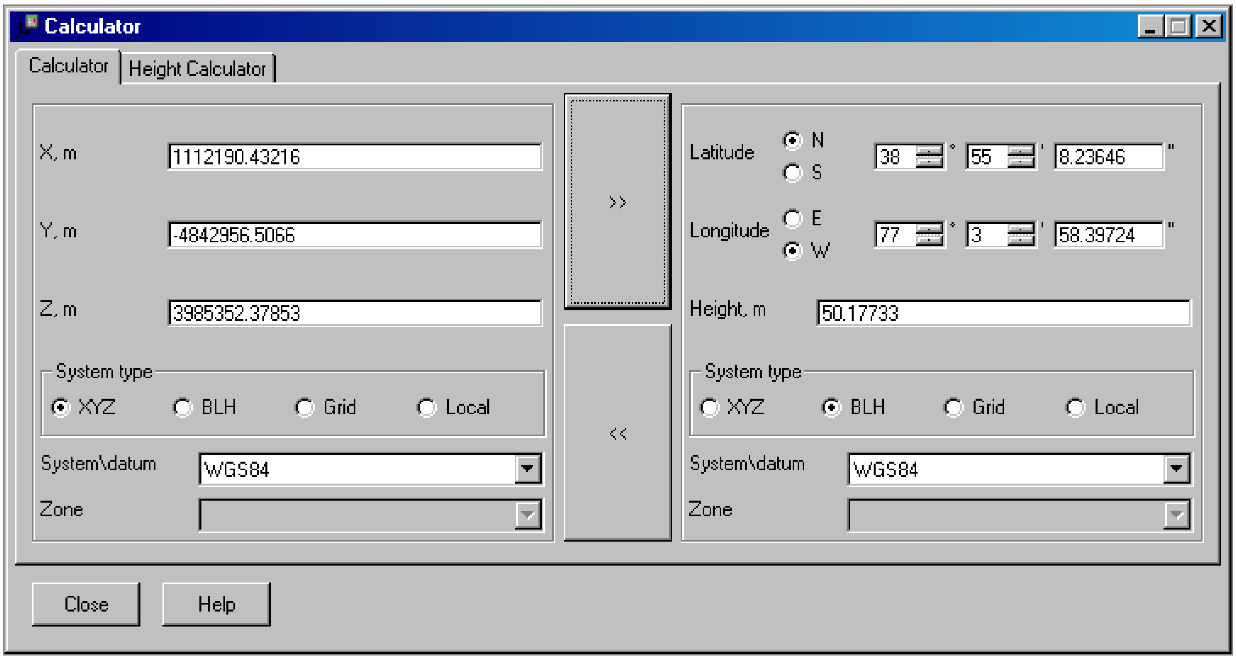


Figure 7-2

Next, use the '*System\Datum*' and, in the case of grid coordinates, '*Zone*' listboxes to choose the desired ***input*** coordinate system and zone, respectively.

Then specify the coordinates themselves in the corresponding edit boxes.

Note that the default coordinate type is ***Geodetic*** ('*BLH*') and the default coordinate system is **WGS84**. Therefore, if the coordinate type or local datum is selected ***after*** the coordinates have been entered, the latter will be **automatically updated!**

For this reason it is recommended to enter data in the '*Calculator*' tab "*from the bottom upwards*".

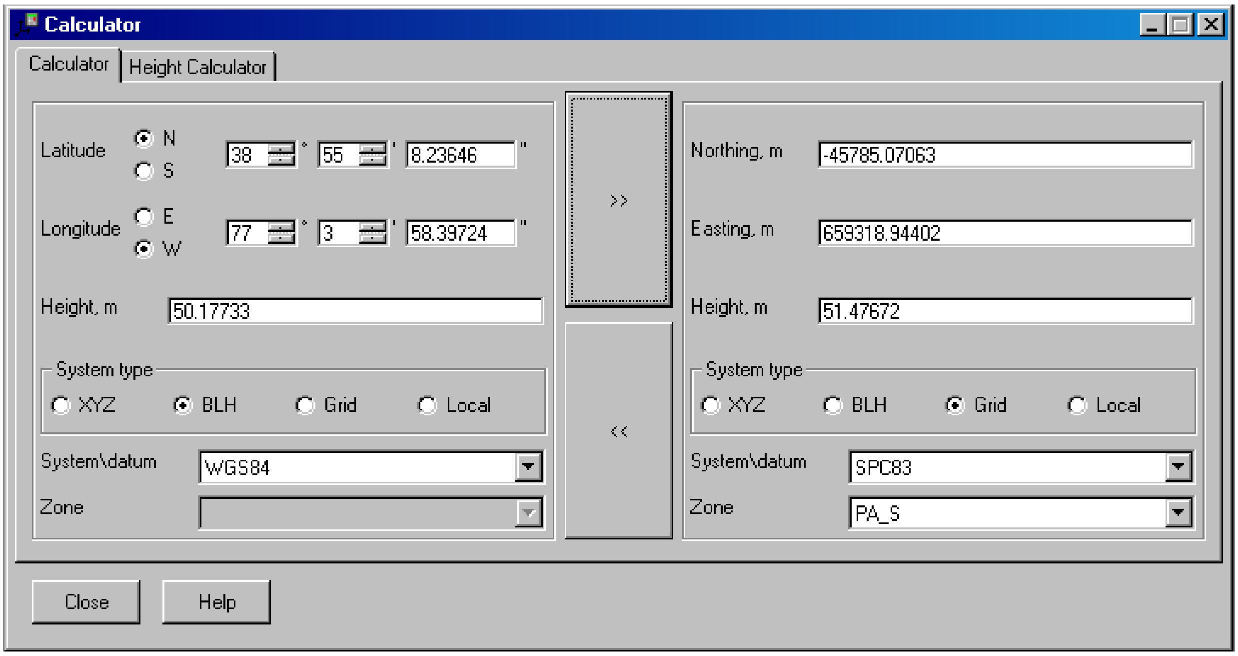


Figure 7-3

Similarly, in the other panel, select the desired ***output*** coordinate system.

Press the "**>>**" (or "**<<**") button to perform the coordinate transformation.

The resulting coordinates will be displayed in the corresponding data fields of the ***output*** panel.

8. *Height Calculator*

Height Calculator is used to transform a point's height from one height system to another.

To activate *Height Calculator*, press the button on the main window's toolbar. The '*Calculator*' window will be opened.

Choose the '*Height Calculator*' tab from the '*Calculator*' window to start *Height Calculator*.

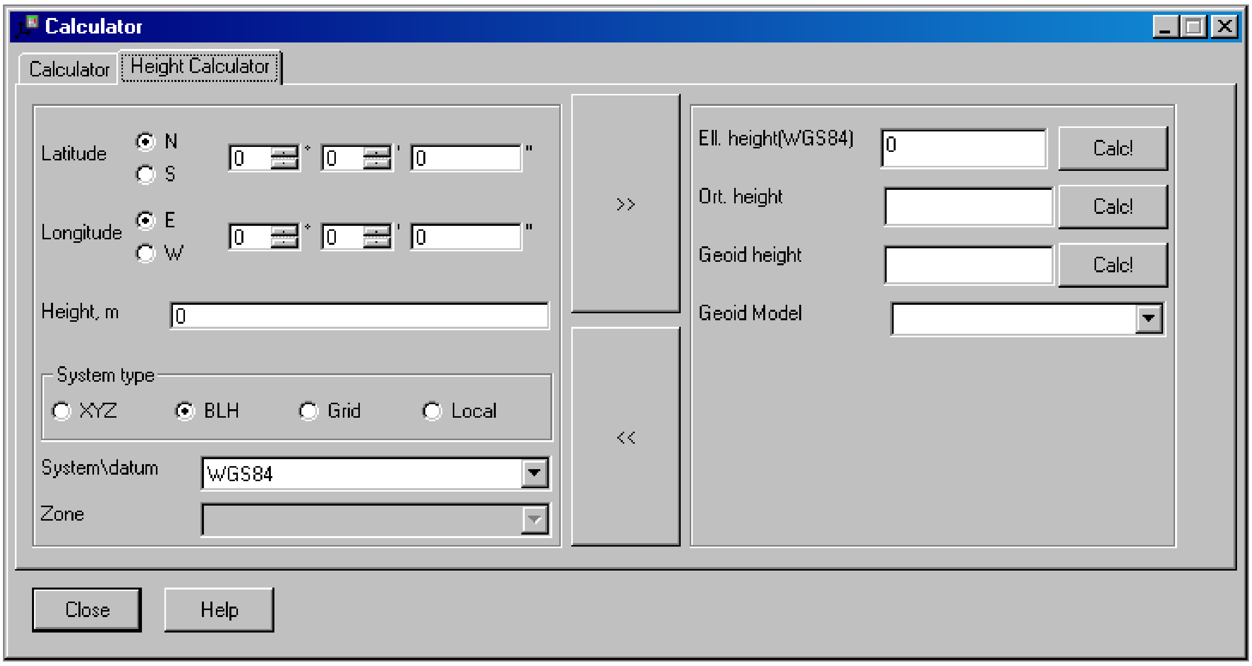


Figure 8-1

This window serves two purposes:

- First, it allows the user to convert ellipsoidal height between orthometric height and geoid undulation.
- Second, it is used to transform coordinates from one system into another when only orthometric (not ellipsoidal) heights are available, i.e., (Lat, Lon, Orth.Height) or (Northing, Easting, Orth.Height).

There are two panels in this window.

The left-hand panel is exactly the same as that in the '*Coordinate Calculator*'s window. This panel is used to enter a point's coordinates.

It is the right-hand panel that has controls to convert heights. The height to be converted may be entered manually. Also, the user may copy an ellipsoidal height from the left-hand panel to the right-hand panel by pressing the "**>>**" button.

Note that ellipsoidal heights in the right-hand panel are always specified in WGS84. When transforming a local ellipsoid height from the left-hand to the right-hand panel, this height will be recalculated from the local datum to WGS84. This means that all height calculations are performed specifically in WGS84.

Geoid height (also referred to as *geoid undulation*) is computed by using the geoid model selected from the *'Geoid Models'* list. This listbox will be active only in the following two cases:

- A global geoid model has been imported into PINNACLE (see Figure 8-2) or
- A regional or local geoid model has been imported that covers the point whose coordinates are specified in the left-hand panel.

Otherwise, if the '*Geoid Models*' listbox is disabled, the point's geoid height will be set to zero.

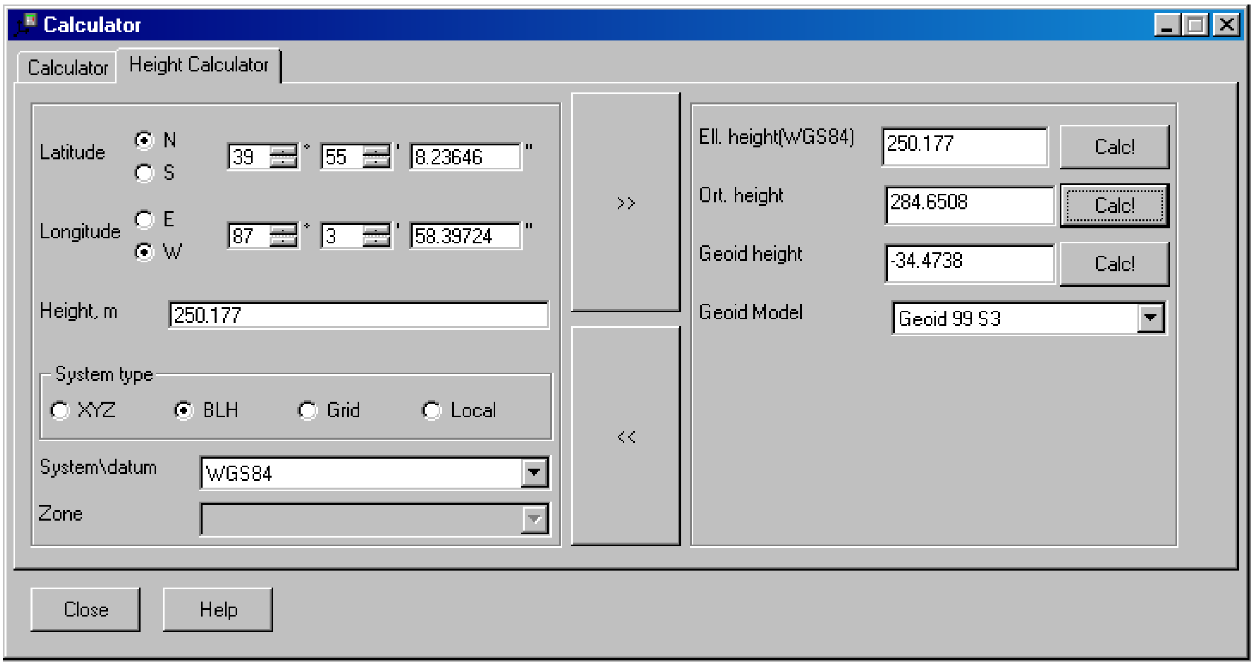


Figure 8-2

To derive the geoid undulation for a point, the user must first specify the point's coordinates in the left-hand panel and then press the "**>>**" button. Next the user must open the '*Geoid Models'* list box, which enumerates all of the geoid models available for the area where the given point is located, and select an acceptable geoid model. Once an appropriate geoid model is chosen, the geoid height (corresponding to this point) will be computed and displayed in the 'G*eoid height'* field.

The ***Calc!*** buttons are used to calculate any one of the three interrelated height values when the other two values are known.

For example, if both the ellipsoidal height and geoid undulation are specified in the *'Ell.height (WGS84)'* and *'Geoid height'* data fields, the orthometric height can be computed with the '***Calc!'*** button closest to the '*Ort.height'* field.

Note that all height calculations are carried out in WGS84, i.e. orthometric and geoid heights are always specified in WGS84. It is only ellipsoidal heights that may be transformed for a local datum.

9. *Table Calculator*

Press the button on the main window's toolbar to activate *Table Calculator*.

The following window will be opened:

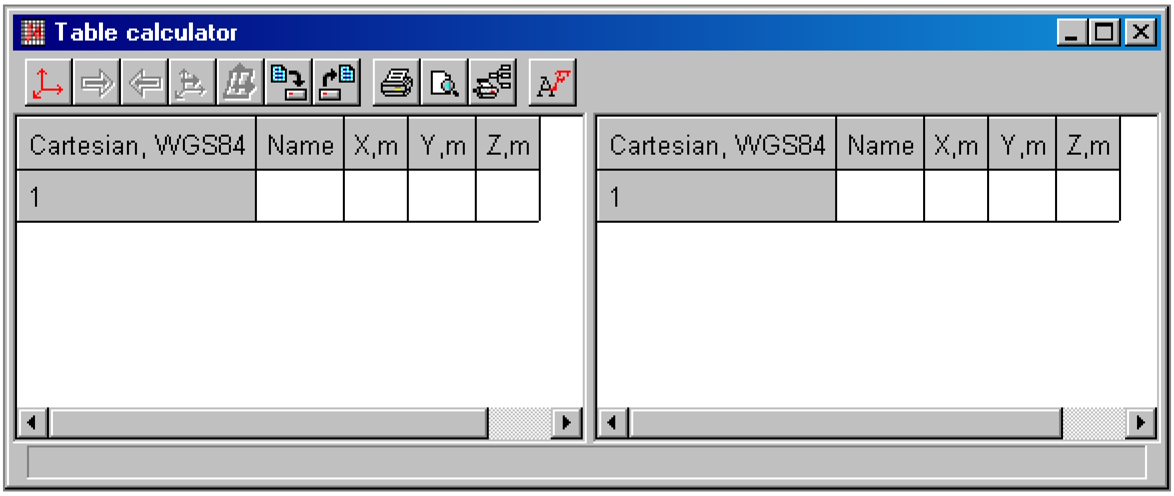


Figure 9-1

The *Table Calculator* window has the following buttons:

Choose/modify the coordinate systems selected in the left-hand and right-hand panels.

Convert the user-input coordinates from the left-hand panel's coordinate system into that specified for the right-hand panel.

Convert the user-input coordinates from the right-hand panel's coordinate system to the left-hand panel's one.

Calculate the Helmert 7-parameter transformation.

Perform the 4-parameter horizontal localization and 3-parameter vertical localization for a local coordinate system.

Export data (point coordinates, system names and units) from either of the Table Calculator's panels into a text file.

Import data (point coordinates, system names and units) from a text file into Table Calculator's panels.

Print the contents of either or both panels.

Print a preview of the contents of either panel.

Page setup.

Font setup.

9.1. How to enter a point's coordinates

Given a point, the user must enter its coordinates in the corresponding data fields (edit boxes). Care should be taken that the proper coordinate system is chosen before typing coordinates,otherwise the user-entered coordinates will be automatically modified to match the user-selected system.

A point's coordinates can be entered manually or copied from:

- the project window's '*SubNets'* panel
- the project window's '*Solutions'* panel
- a *control data list*.

In all these cases PINNACLE's internal buffer is used (not the Windows clipboard).

If the user wants to copy the points' coordinates from either the '*Solutions'* or '*SubNets'* panel, it is necessary to expand the corresponding panel's tree, check the desired points, right-click on any one of the checked points and select '*To Buffer'* from the pop-up menu.

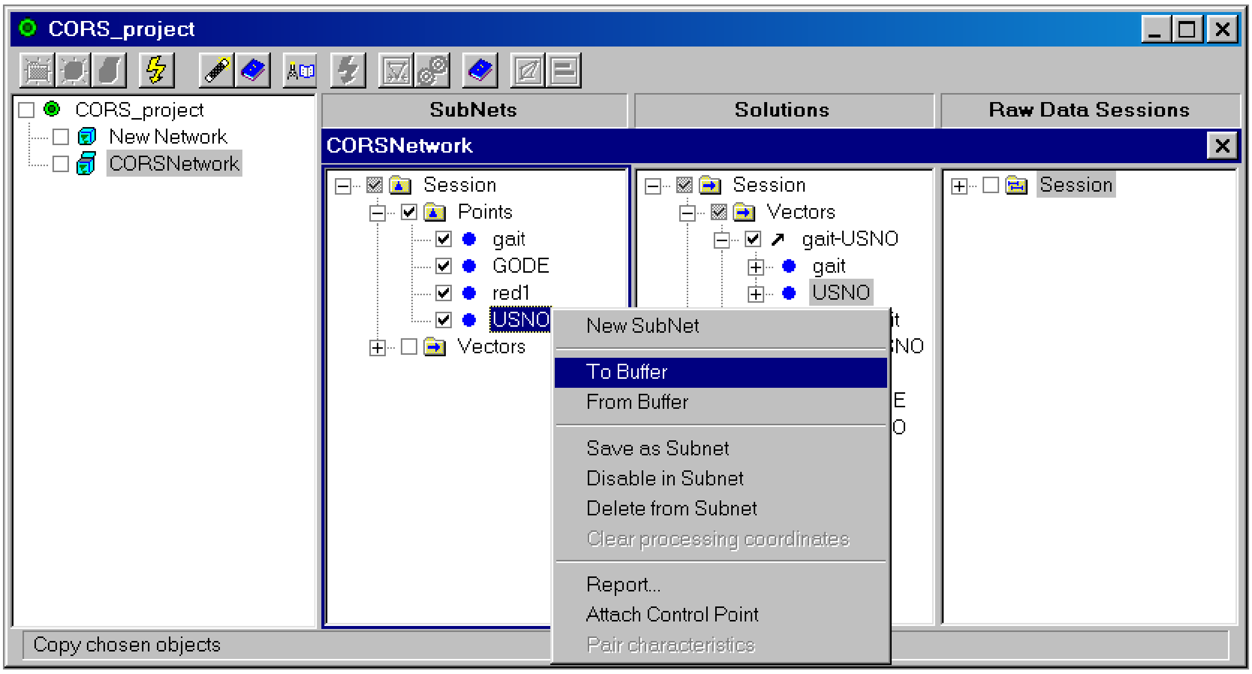


Figure 9-2

If the user wants to copy the points' coordinates from a *control data* list, it is necessary to select all of the desired points by clicking on them while holding down the *Shift* or *Ctrl* key, then right-click on any one of the highlighted points and select '*To Buffer'* from the pop-up menu.

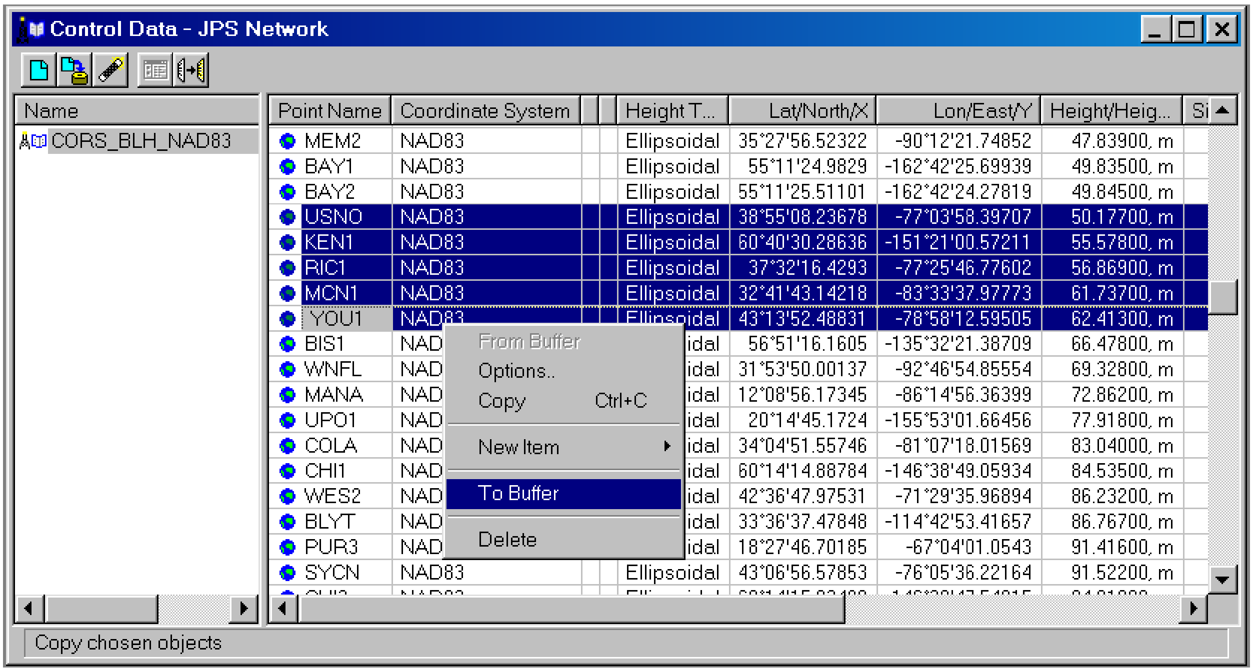


Figure 9-3

To download the points' coordinates from the buffer into *Table Calculator*, the user must right-click anywhere in the corresponding panel and select '*From Buffer*' from the pop-up menu.

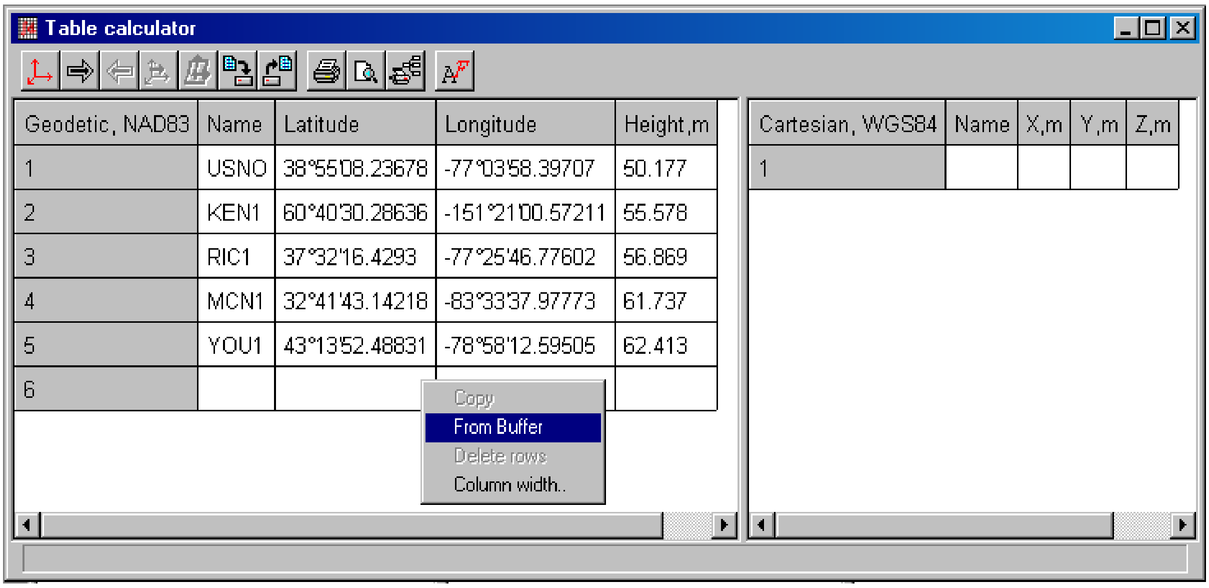


Figure 9-4

If there are no points specified in this panel initially, the coordinates to be copied from the buffer will remain as they are in the original coordinate system. Otherwise these coordinates will first be transformed into the selected system. If such transformation fails, the points kept in the buffer will not be downloaded into the '*Table calculator*' window.

When copying a *control data list*, its points' coordinates will not be transformed. The coordinate system applied to the corresponding panel will coincide with that associated with the first item of the first control point. For each point, only one (or none) of its items can be copied. If none of the point's items belongs to this coordinate system, this point will not be copied into the corresponding panel at all.

Note. If the points displayed in the table calculator's panel are specified in a coordinate system different from that used for the control data list, no points will be copied from the CDL into the table calculator.

9.2. How to select a coordinate system

Press the '*Choose systems* button to select/modify the coordinate systems for the left-hand and right-hand panels.

Pressing this button will invoke the '*Choose system'* dialog box:

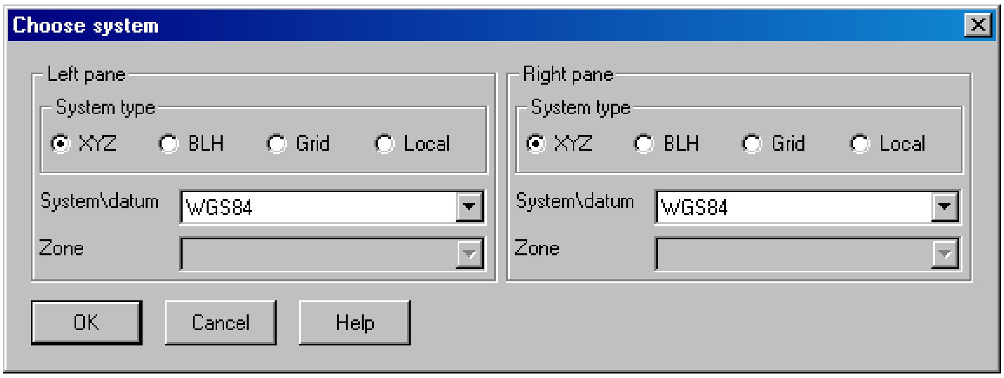


Figure 9-5

The '*System type'* radio button groups allow the user to select the coordinate type: Cartesian (*"XYZ"*), Geodetic (*"BLH"* - *Latitude, Longitude, Ellipsoidal Height),* Grid *("NEU" - Northing* and *Easting* based on a map projection, *Optometric Height)* or Local *("NEU"* - conventional *x, y* and *height)*.

Note that Cartesian coordinates (XYZ in WGS84) are used by default.

For XYZ (Cartesian) system the panel looks like this:

Cartesian, WGS84	Name	X,m	Y,m	Z,m
1				

Figure 9-6

For BLH (Geodetic) system:

Geodetic, WGS84	Name	Latitude	Longitude	Height,m
1				

Figure 9-7

For Grid system:

Grid, AMG, Zone_31 : 0E to 6E	Name	Northing,m	Easting,m	Height,m
1				

Figure 9-8

For Local system:

Local, Local_USF	Name	Northing,ft	Easting,ft	Height,ft
1				

Figure 9-9

The '*System\datum*' and '*Zone*' listboxes[2] allow selection of an appropriate datum and zone, respectively.

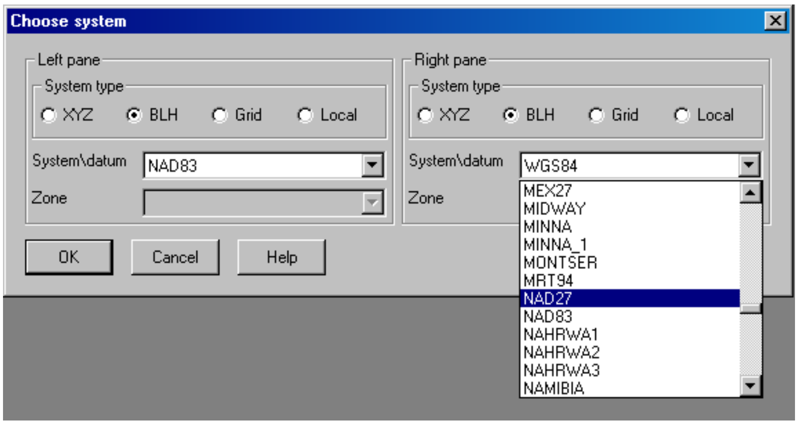


Figure 9-10

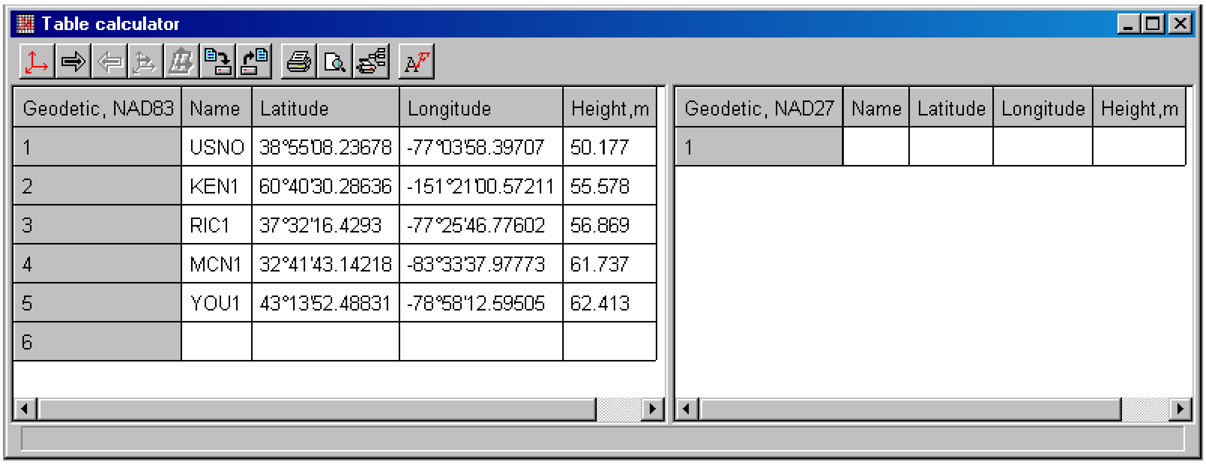


Figure 9-11

9.3. How to perform a coordinate transformation

The *Transform…* buttons and shown on the *Table calculator* window's toolbar allow conversion of the user-entered coordinates between the coordinate systems specified for the left-hand and right-hand panels.

The *Transform from left to right* button is used to convert the user-entered coordinates from the left-hand panel's coordinate system into the right-hand panel's.

The *Transform from right to left* button is used to convert the user-entered coordinates from the right-hand panel's coordinate system into the left-hand panel's.

If one of the panels is empty and identical coordinate systems are set for both panels, these buttons can by used for copying coordinates from one panel into the other.

Note that either button will be active only if the corresponding panel is not empty.

[2]) the 'Zone' listbox is rellevant only to grid coordinates

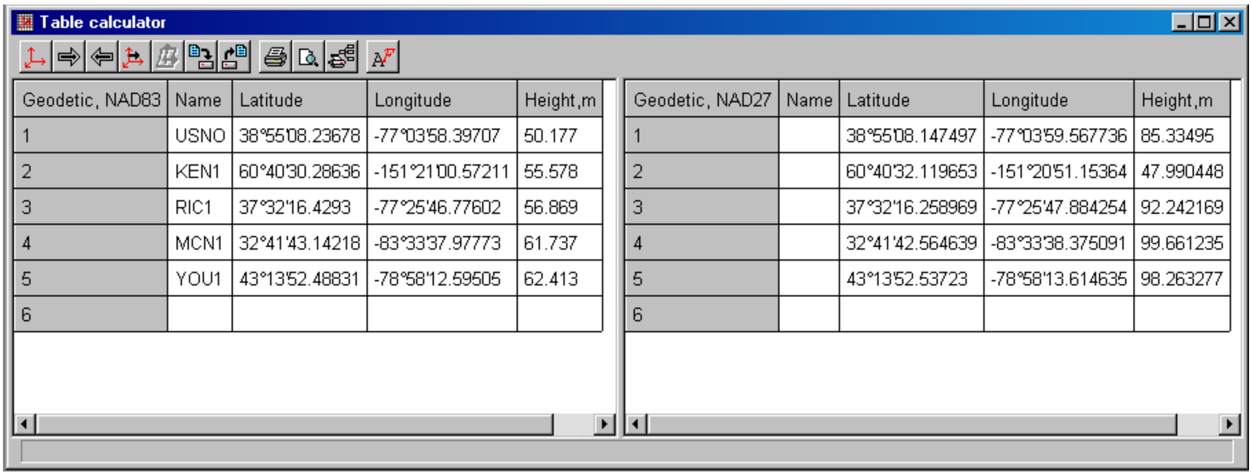


Table calculator

Geodetic, NAD83	Name	Latitude	Longitude	Height,m
1	USNO	38°55'08.23678	-77°03'58.39707	50.177
2	KEN1	60°40'30.28636	-151°21'00.57211	55.578
3	RIC1	37°32'16.4293	-77°25'46.77602	56.869
4	MCN1	32°41'43.14218	-83°33'37.97773	61.737
5	YOU1	43°13'52.48831	-78°58'12.59505	62.413
6				

Geodetic, NAD27	Name	Latitude	Longitude	Height,m
1		38°55'08.147497	-77°03'59.567736	85.33495
2		60°40'32.119653	-151°20'51.15364	47.990448
3		37°32'16.258969	-77°25'47.884254	92.242169
4		32°41'42.564639	-83°33'38.375091	99.661235
5		43°13'52.53723	-78°58'13.614635	98.263277
6				

Figure 9-12

9.4. How to calculate a 7-parameter transformation

The '*Calculate 7 parameters'* button on the '*Table calculator'* window's toolbar allows the user to calculate the Helmert 7-parameter datum transformations.

The '*Calculate 7 parameters*' button is enabled only if the following two conditions are met:

- More then three points are available for datum transformation
- One of the two systems is WGS84.

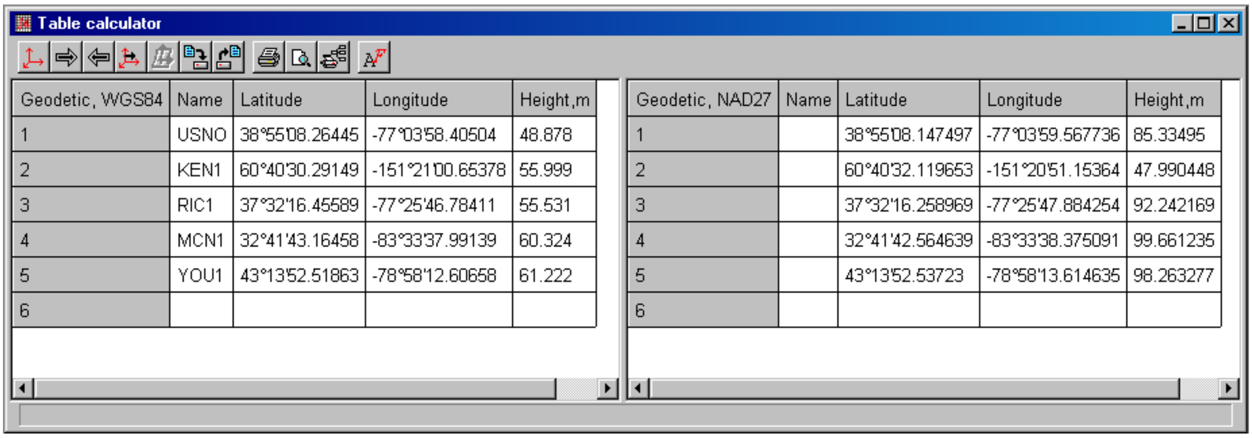


Table calculator

Geodetic, WGS84	Name	Latitude	Longitude	Height,m
1	USNO	38°55'08.26445	-77°03'58.40504	48.878
2	KEN1	60°40'30.29149	-151°21'00.65378	55.999
3	RIC1	37°32'16.45589	-77°25'46.78411	55.531
4	MCN1	32°41'43.16458	-83°33'37.99139	60.324
5	YOU1	43°13'52.51863	-78°58'12.60658	61.222
6				

Geodetic, NAD27	Name	Latitude	Longitude	Height,m
1		38°55'08.147497	-77°03'59.567736	85.33495
2		60°40'32.119653	-151°20'51.15364	47.990448
3		37°32'16.258969	-77°25'47.884254	92.242169
4		32°41'42.564639	-83°33'38.375091	99.661235
5		43°13'52.53723	-78°58'13.614635	98.263277
6				

Figure 9-13

Note that identical physical points may have different names when specified in the left-hand and right-hand panels. Any two points occupying the same row in both panels are assumed to define one and the same physical point. When the number of points in one panel is different from the number of points in the other panel, Pinnacle will take into account only the rows available in either panel, discarding the rest of the points in the 'longer' panel.

If the calculation process fails, the message *"Error in 7 parameters calculation"* will be reported:

Figure 9-14

If the calculation is successful, the results will be shown in the '*Datum Parameters and Transformation Residuals'* window.

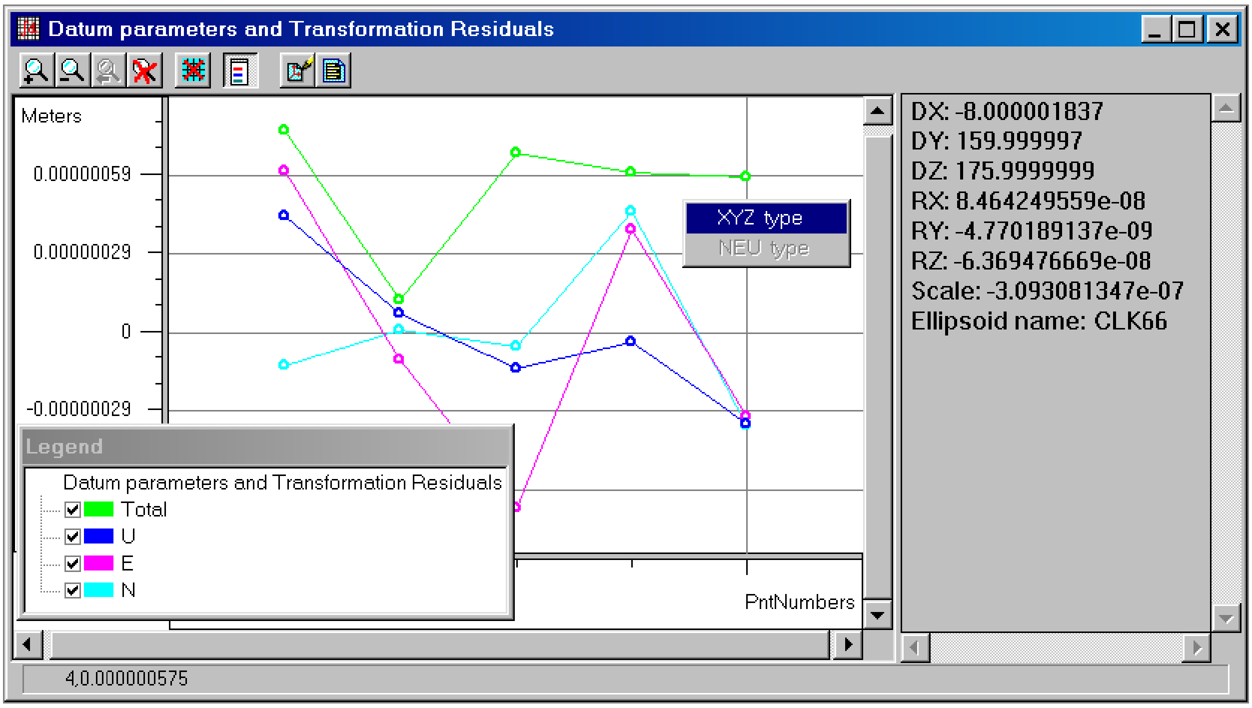


Figure 9-15

By default, the transformation residuals are computed in the NEU system. To change NEU to the XYZ-system, right-click somewhere in the '*Transformation Residuals'* panel and select '*XYZ*'.

The *'Legend'* window can be turned on and off with the toolbar's '*Show or hide legend'* button.

The button governs the way in which the grid lines are drawn in the window (***on*** or ***off***, ***under*** and ***over*** the residual graph).

The transformation residuals may also be shown in a table format. To do this, press the '*Show table'* button. The following window will be opened:

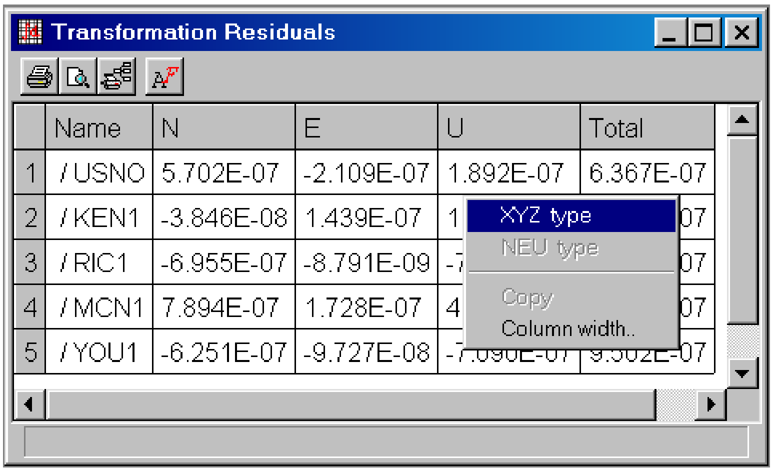


Figure 9-16

By default, the residuals are displayed in this table in the same format as has been selected for the graphic representation. To change the format, right-click somewhere in the '*Transformation Residuals window'* and select the desired format.

The analysis of the transformation residuals helps the user detect possible blunders in the WGS84 or local coordinate sets. The user can identify the points having critical or abnormal residuals. To check on a suspectpoint, exclude this point from both panels and re-compute the transformation parameters. If the updated residuals look satisfactory and the problem appears to be fixed, then this indicates that it was a suspect point. If the problem persists, the user should put the point back into the corresponding panels and then repeat the entire *filtration procedure* for the second-worst point, etc. Note that this blunder detection mechanism proves effective only if the user has enough redundant points and the points' geometry (configuration) is good enough, for example, if the common points are "uniformly distributed" over the area of interest.

If the user finds the resulting residuals small enough, the transformation parameters calculated may be added to the list of the datum parameters. For this, use the '*Save datum'* button . After pressing the button, a dialog window will appear, prompting the user to enter the datum name and a comment:

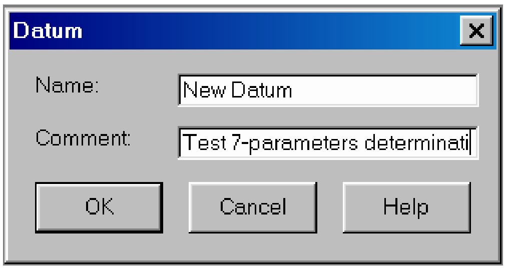


Figure 9-17

It is possible to add a new datum or update any of the existing user-defined datums. In the latter case, a detailed comment is recommended.

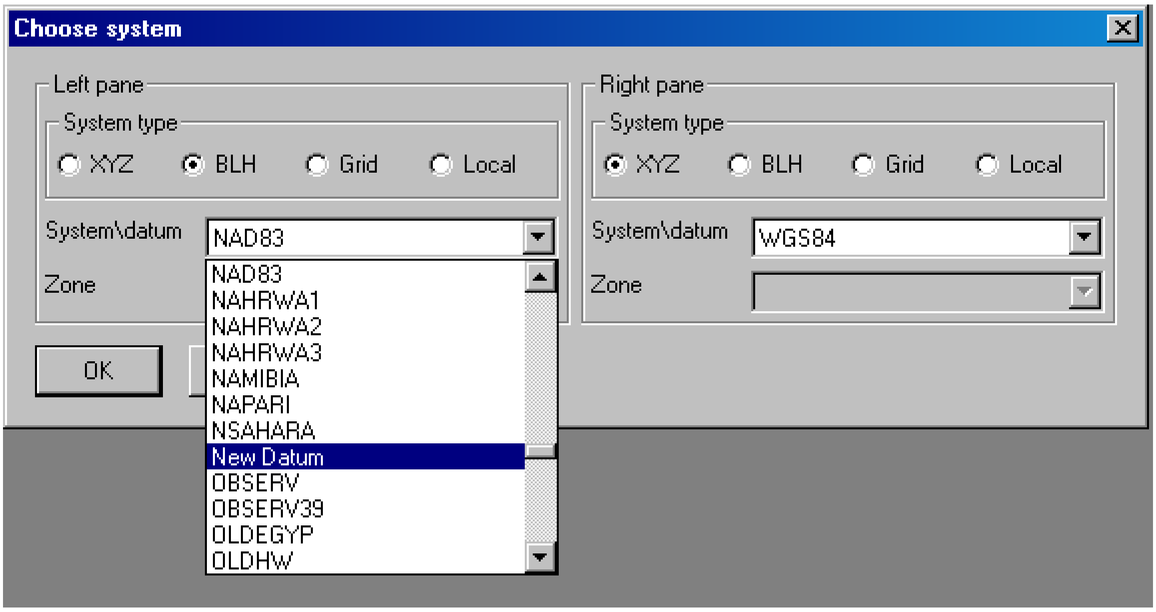


Figure 9-18

The user can then employ the new datum parameters for transforming the rest of the points from the panel with the longer point list. For this, return to the '*Table Calculator'* window and replace the target coordinate system with the newly defined datum.

9.5. How to run localization

The '*Calculate local parameters*' button , which is located on the '*Table calculator*' window's toolbar, allows the user to accomplish the 4-parameter horizontal and 3-parameter vertical localization tasks for a local coordinate system.

The '*Calculate local parameters*' button is enabled only if the following two conditions are met:

- More then three points are available for the localization.
- One of the two systems used in localization must be WGS84 and the other is specified as Local.

To perform localization, the user needs to take the following steps:

1) Press the button on the 'Table Calculator' window's toolbar. The following dialog window will appear.

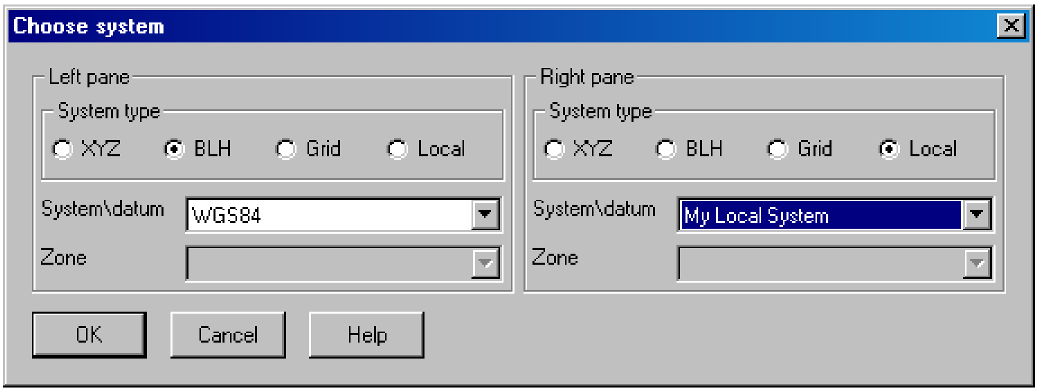
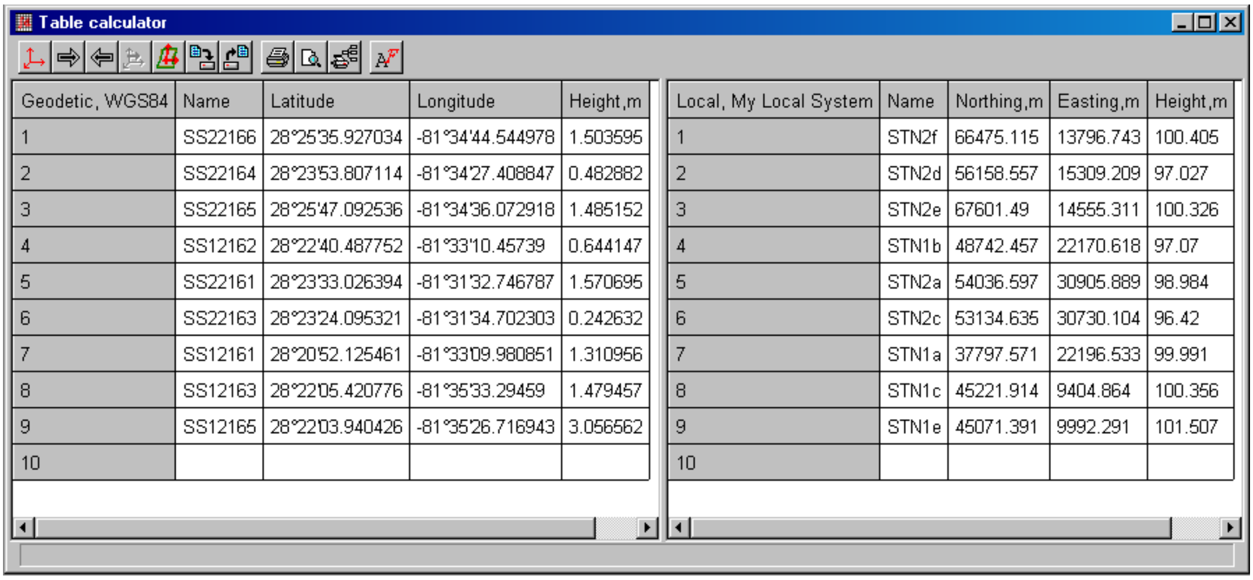


Figure 9-19

Check the *'Local'* radio button and select the required local system from the "System/Datum" pulldown list.

2) Either enter the points' coordinates in the local system manually or import an appropriate control data list in which the points are specified in the given local system. Highlight the desired points the 'Control Data' window's right-hand panel and then download them into the 'Table Calculator' window's right-hand panel by means of the '*To Buffer - From Buffer*' option.

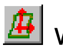


Geodetic, WGS84	Name	Latitude	Longitude	Height,m
1	SS22166	28°25'35.927034	-81°34'44.544978	1.503595
2	SS22164	28°23'53.807114	-81°34'27.408847	0.482882
3	SS22165	28°25'47.092536	-81°34'36.072918	1.485152
4	SS12162	28°22'40.487752	-81°33'10.45739	0.644147
5	SS22161	28°23'33.026394	-81°31'32.746787	1.570695
6	SS22163	28°23'24.095321	-81°31'34.702303	0.242632
7	SS12161	28°20'52.125461	-81°33'09.980851	1.310956
8	SS12163	28°22'05.420776	-81°35'33.29459	1.479457
9	SS12165	28°22'03.940426	-81°35'26.716943	3.056562
10				

Local, My Local System	Name	Northing,m	Easting,m	Height,m
1	STN2f	66475.115	13796.743	100.405
2	STN2d	56158.557	15309.209	97.027
3	STN2e	67601.49	14555.311	100.326
4	STN1b	48742.457	22170.618	97.07
5	STN2a	54036.597	30905.889	98.984
6	STN2c	53134.635	30730.104	96.42
7	STN1a	37797.571	22196.533	99.991
8	STN1c	45221.914	9404.864	100.356
9	STN1e	45071.391	9992.291	101.507
10				

Figure 9-20

Note that the points must be arranged in the same order on the left and right-hand panels of the 'Table Calculator' window. This is necessary because the one-to-one correspondence between the data displayed on the two opposite panels is based exclusively on the *row numbers*, not the point names. When the number of points in one panel is different from the number of points in the other, Pinnacle will take into account only the rows available on the 'shorter' panel discarding any 'unmatched' points on the 'longer' one.

3) Once there are at least three points entered in either panel, the button  will become active.

   Press this button to compute the localization parameters.

If the calculation process fails, the message *"Error in local parameters calculation"* will be reported:

Figure 9-21

If the calculation is successful, the results will be shown in *'Transformation Residuals'* window:

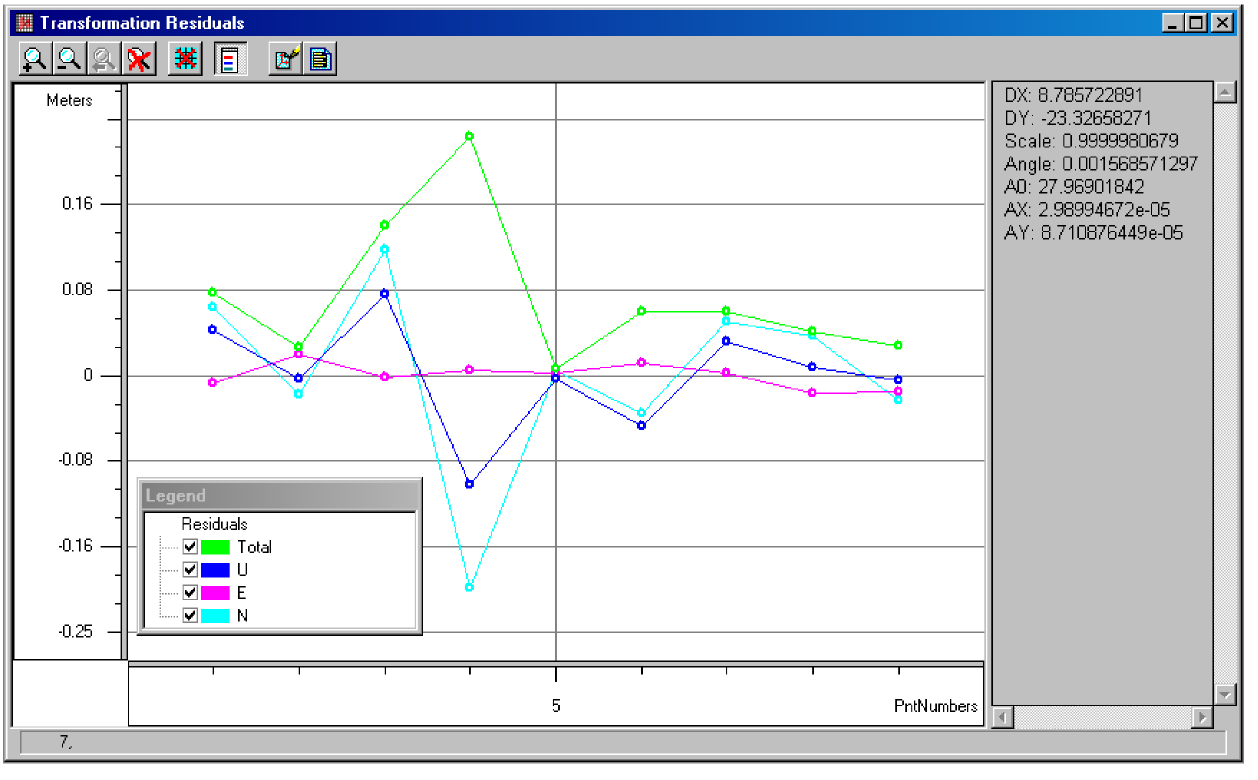


Figure 9-22

In this window the user will see *seven* localization parameters: *four* (4) for plane and *three* (3) for height. Here the user can view, either in graphic or tabular form, the computed residuals. (To switch to tabular, the button  needs to be pressed).

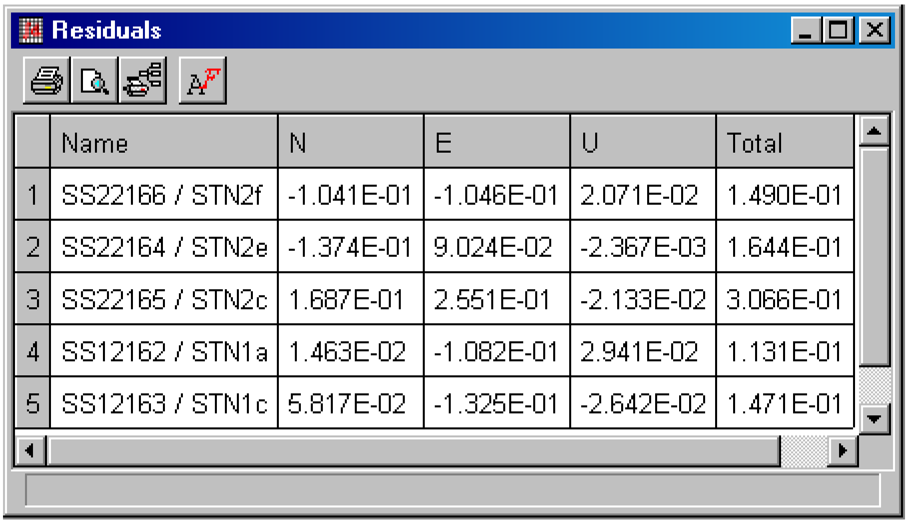


Figure 9-23

By pressing the button, the computed localization parameters can be saved to disk using either the local system's original name or a new name. In the second case a new local system will be created.

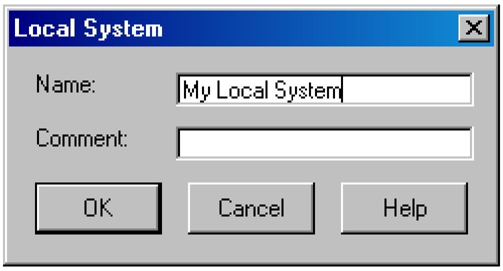


Figure 9-24

Note that the user can view these parameters later (but cannot edit them!)

If the user closes the *'Transformation Residuals'* window without saving the computed localization parameters, the following dialog box appears:

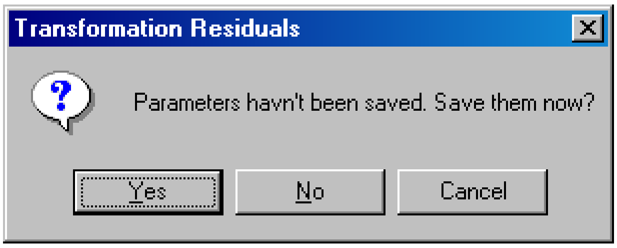
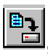
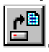


Figure 9-25

Once the parameters are successfully saved, this local coordinate system can be used throughout Pinnacle.

9.6. How to export data from Table Calculator into a text file

The *'Write data'* button , which is located on the *'Table calculator'* window's toolbar, is used to export data from either of the Table Calculator's panel into a text file. These data, i.e. the system names, units and point coordinates, after they have been exported, can be imported back to either of the Table Calculator's panels with the button .

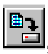
After pressing the button , a dialog box will appear, prompting the user to select one or both of the panels:

Figure 9-26

Note that the options *'Right panel'* or *'Left panel'* will be available for data export only if the corresponding panel is NOT empty.

Once the desire adoption is selected, a standard *'Save As'* dialog window will appear prompting the user to export data to file:

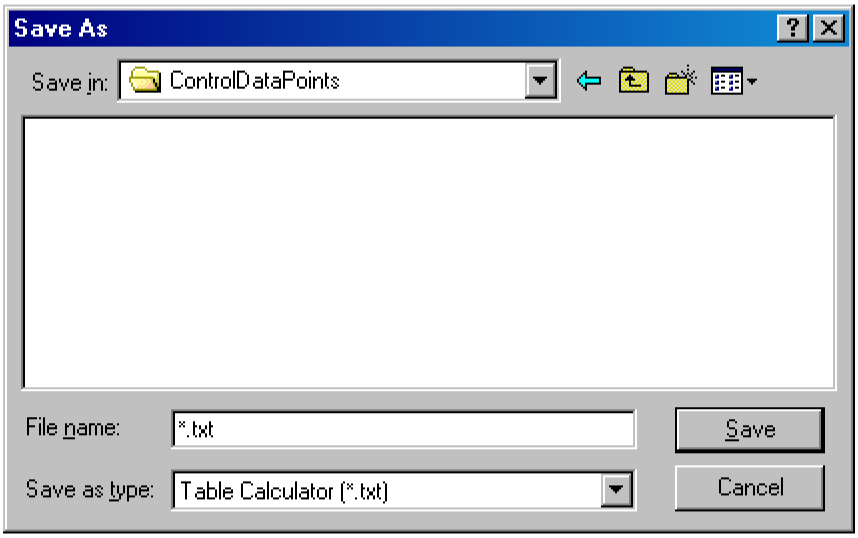


Figure 9-27

9.7. How to import data from a text file into Table Calculator

The *'Load data'* button from the *'Table calculator'* window's toolbar is used to import data from a text file into either of the Table Calculator's panels. The user will be able to import data if, and only if, these data have earlier been exported from the 'Table Calculator' with the button .

After pressing the button , a dialog box will appear prompting the user to select one of the three options:

Figure 9-28

Note that the option *'Right panel'* or *'Left panel* will be enabled for data import only if the corresponding panel is empty.

After the desired option is selected, a standard *'Open File'* dialog window will appear prompting the user to specify the destination.

9.8. How to print results

The following four buttons from the '*Table calculator*' window's toolbar,

are used to configure the printer before printing results.

Pressing the button will invoke a standard ' *Font Setup'* dialog window:

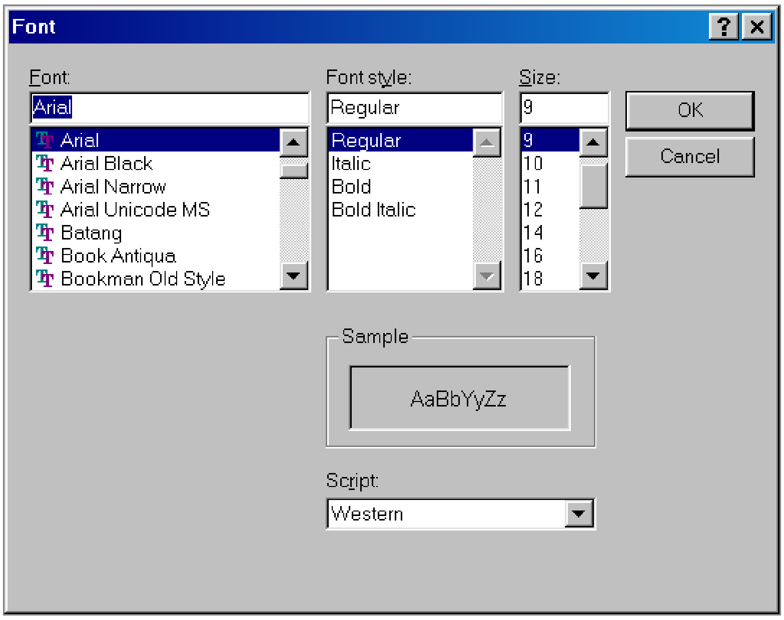


Figure 9-29

Pressing the button will launch a *'Page Setup'* dialog window as shown below:

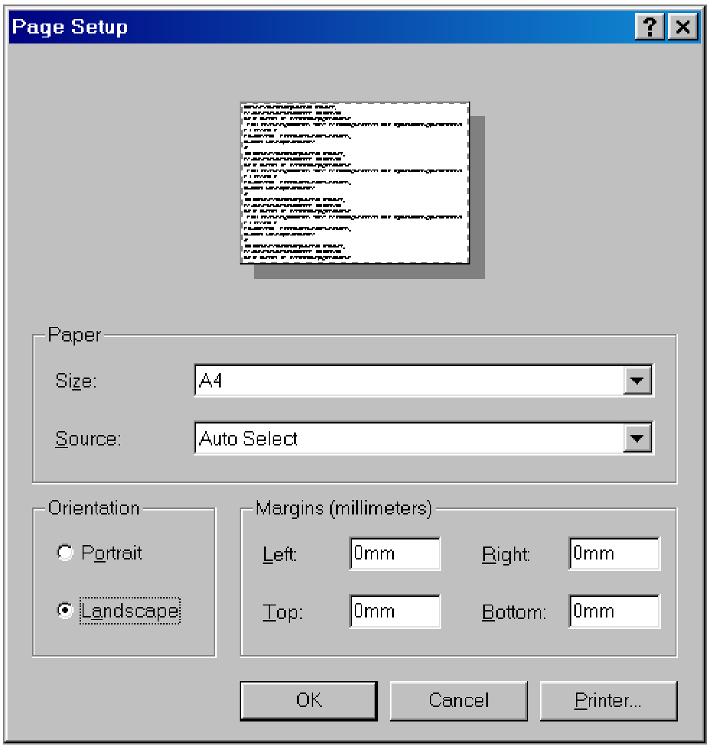


Figure 9-30

With the  button, the user can open a standard '*Print Setup'* dialog window. If this button is pressed, the following prompt will first pop up:

Figure 9-31

The user will need to select the panel to be printed. Then a standard '*Print Setup'* dialog window will be opened as shown in Figure 9-32:

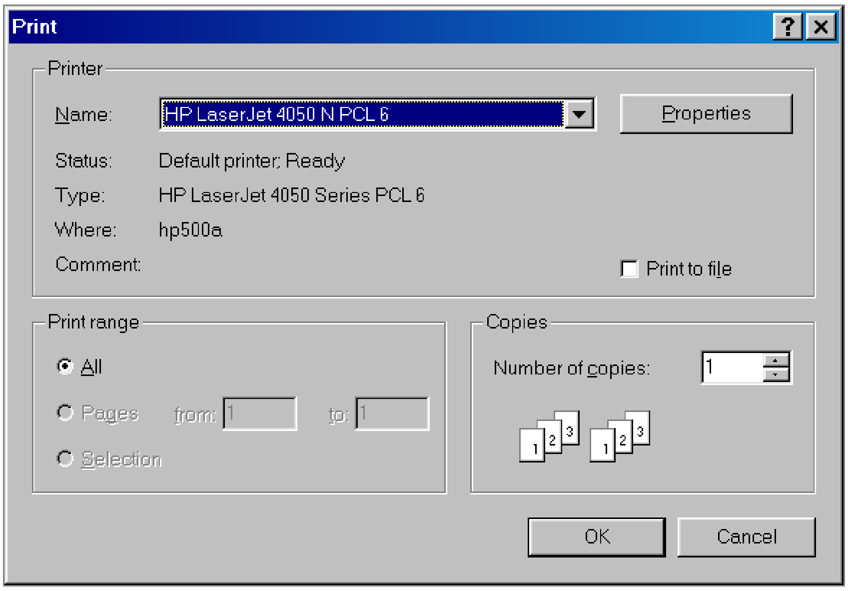


Figure 9-32

Note that the last two dialog windows (i.e. Figure 9-30 and Figure 9-32) can also be opened with the buttons '*Print'* and '*Page Setup'* shown at the bottom of the '*Print Preview'* dialog window (see Figure 9-34).

Pressing the button '*Print Preview*'  will invoke the following prompt:

Figure 9-33

After the user selects the table calculator's panel to be printed, the following '*Print Preview*' dialog window will be opened:

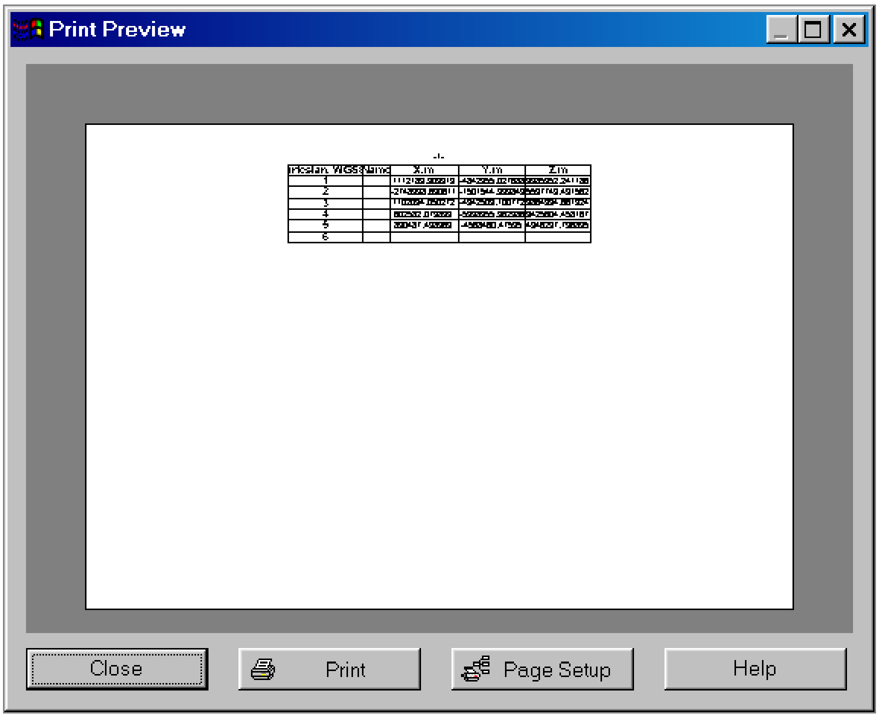


Figure 9-34

10. *Geoid Models*

PINNACLE provides various geoid models. They are all included in the '*Geoid Model'* list. Note that geoid heights (geoid undulations) are used in the following two PINNACLE's modules:

- Adjustment
- Height calculator.

10.1. Geoid Models List

Press the '*Coordinate System Editor*' button  on the toolbar in Pinnacle's main window. The '*Coordinate System and Geoid Editor*' dialog window will be opened:

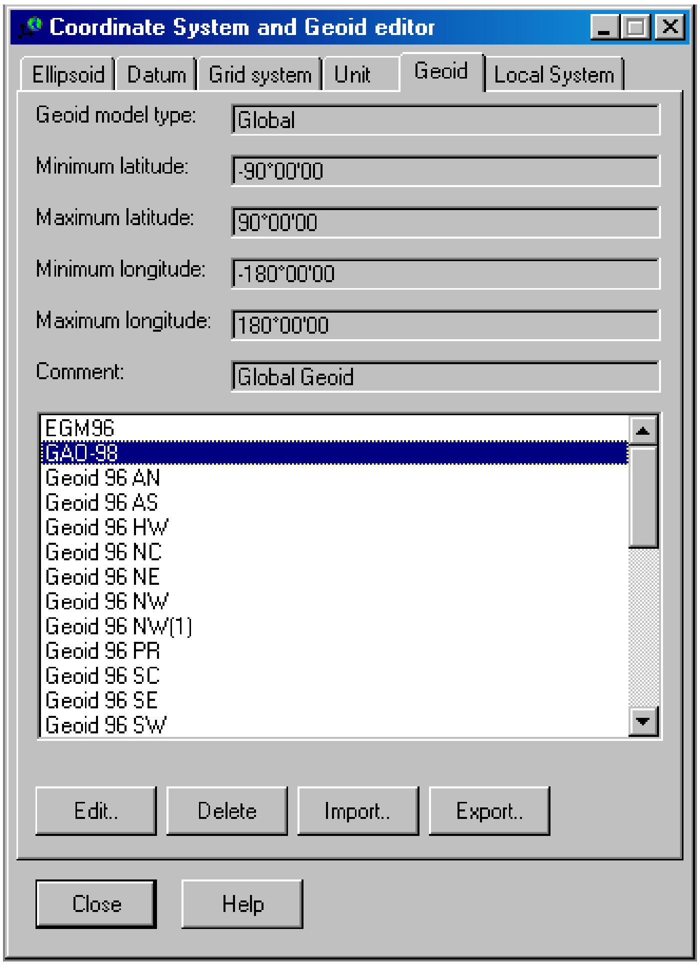


Figure 10-1

To view or edit the '*Geoid Models'* list, choose the '***Geoid'*** tab.

The list contains the geoid models' names.

If a geoid model is highlighted, the user will see the following geoid properties:

- geoid model's type;
- limitations on the use of this model.

The following buttons are available in the *'**Geoid'*** tab:

The ***'Edit…'*** button is used to edit the geoid models presented in the list.

The ***'Delete'*** button allows the user to remove unnecessary geoid models from the list.

The ***'Import…'*** button is used to add new geoid models to the '*Geoid Models'* list. (They are loaded into PINNACLE's database from an external file.)

The ***'Export…'*** button allows the user to export a selected geoid model into a ****.jff*** file.

10.2. Geoid Model Types

PINNACLE supports the following three geoid model types:

- global;
- regional;
- local.

A **global** geoid model is presented as a set of fully normalized coefficients describing the gravitational potential as a series expansion of orthogonal spherical functions. Global models enable the user to compute geoid height for any point on the Earth.

A **regional** geoid model is an array of geoid heights specified for the nodes of a regular grid. Regional models normally cover quite large territories. For example, a regional model may be applicable throughout a country.

A **local** geoid model is a set of geoid heights specified for several pre-defined points distributed within a limited area (e.g., a project area) in an arbitrary way (sometimes *irregularly* and *non-uniformly*). Local geoid models are obtained by using the differences between the GNSS-observed ellipsoidal heights and the known orthometric heights when vertical control is available.

10.3. How to import a geoid model

In PINNACLE, it is possible to import global and regional models.

The ***'Import…'*** button is used to add new geoid models to the '*Geoid Models'* list.

After pressing this button, a standard *File|Open* dialog window will be opened:

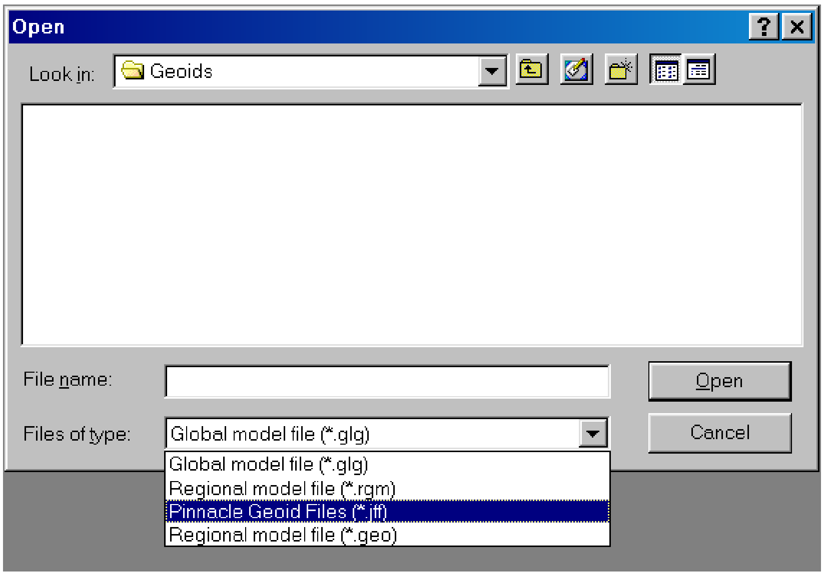


Figure 10-2

The user can select the desired file format as shown in Figure 10-2.

Geoid model file formats will have the following extensions

(1) ***.glg** (text),

(2) ***.rgm** (text),

(3) ***.geo** (binary)

(4) ***.jff** (binary)

Note that in PINNACLE all geoid models are assumed to be referenced to WGS84. If a geoid model is originally referenced to a datum other than WGS84, the user should tailor this geoid model to WGS84 prior to importing it to Pinnacle.

Pinnacle geoid files will have the extension ***.jff**.

Note. Two global geoid models (EGM96, GAO-98) and two regional geoid models for the USA territory (Geoid 96, Geoid 99) are currently available to download from the Topcon Positioning System website (http://www.topconps.com/).

10.3.1. How to import a global geoid model from a text file

Global geoid models may be imported not only from ***.jff** files but also from text files.

In such text files, each line will contain the degree and order for the corresponding coefficients (two integers), the "cosine" and "sine" coefficients (two float numbers) and, if available, the coefficients' RMS values (also float values).

A global model file can start with some comment lines, which are disregarded when the geoid data are read in. A comment line may begin with any symbol other than a digit. Spaces are disregarded at any place in the file.

The actual data format (the number of positions used to keep geoid coefficients, degree and order and their place in the line) is determined automatically while reading in the first meaningful line. Note that this starting line must have delimiters. The other lines do not necessarily have to have delimiters.

In addition, the program is able to read in data specified in the following "delimiter-free" format:

degree number — 3 digits;

order number — 3 digits

coefficients — 19 positions (12-digit mantissa)

For example,

```
0        1         2         3         4
1234567890123456789012345678901234567890123 4
  4  2 0.350729847400D-06 0.663967363224D-06
```

Figure 10-3

10.3.2. How to import a regional geoid model

Regional geoid models may be imported not only from ***.jff** files but also from text files. Regional geoid models, represented as binary files, can be imported to PINNACLE only on the condition that their format coincides with that of the GEOID96 or GEOID99 models. Such geoid files will have the extension ***.geo**. If the selected file has a different format, the following error message will be reported:

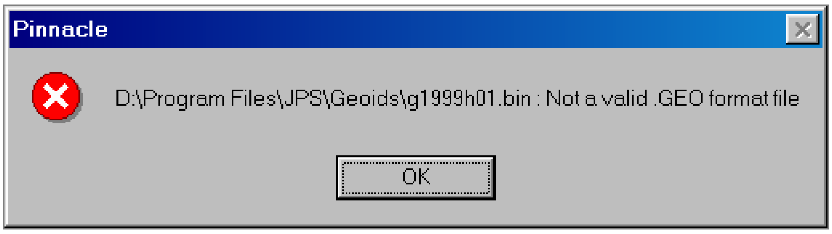


Figure 10-4

Alternatively, the user can import regional models that are presented as text files.

Pinnacle allows the following two text file formats:

Text format #1: It is the AUSGeoid98 data format used by Australia's National Mapping Agency.

According to this format, the starting line must contain the geoid model name:

```
AUSGeoid98 V1.0                              www.auslig.gov.au
```

Figure 10-5

The other lines:

```
(a)  (b)    (c)          (d)                 (e)       (f)
GEO  -19.888 S29 54  0.000 E122 54  0.000     -6.50      0.10
GEO  -19.889 S29 54  0.000 E122 56  0.000     -6.61     -0.03
GEO  -19.887 S29 54  0.000 E122 58  0.000     -6.70     -0.26
GEO  -19.881 S29 54  0.000 E123  0  0.000     -6.64     -0.45
GEO  -19.873 S29 54  0.000 E123  2  0.000     -6.64     -0.70
GEO  -19.859 S29 54  0.000 E123  4  0.000     -6.64     -0.93
GEO  -19.844 S29 54  0.000 E123  6  0.000     -6.48     -1.03
```

Figure 10-6

The Columns (a),…,(f) designate the following:

(a) Geoid record indicator

(b) GRS80/WGS84 geoid undulation value (meters)

(c) Latitude (GDA94/WGS84 - degrees, minutes and seconds)

(d) Longitude (GDA94/WGS84 - degrees, minutes and seconds)

(e) Deflection of the vertical in the meridian (arc seconds) where the deflection is defined as 'astro' latitude minus 'geodetic' latitude (positive north, negative south)

(f) Deflection of the vertical in the prime vertical (arc seconds) where the deflection is defined as ('astro' longitude minus 'geodetic' longitude)*Cos(latitude) - (positive east, negative west)

The columns (e) and (f) are ignored by PINNACLE.

The AUSGeoid98 geoid files have the extension ***.rgm***.

If the selected file, which is assumed to meet the AUSGeoid98 specifications, proves to have a different format, the following error message will be reported:

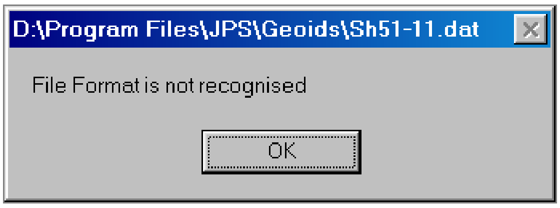


Figure 10-7

Text format #2: Geoid heights must be written in the file in either of the following two ways:

- along the parallel eastwards, starting from the northernmost parallel down to the southernmost one;
- along the parallel eastwards, starting from the southernmost parallel

Each row will contain geoid heights separated by spaces.

The way the geoid heights are arranged, the coordinates of the starting point, the number of columns and rows in the model, and the model's regular grid steps along the meridians and parallels will be specified in the corresponding dialog window.

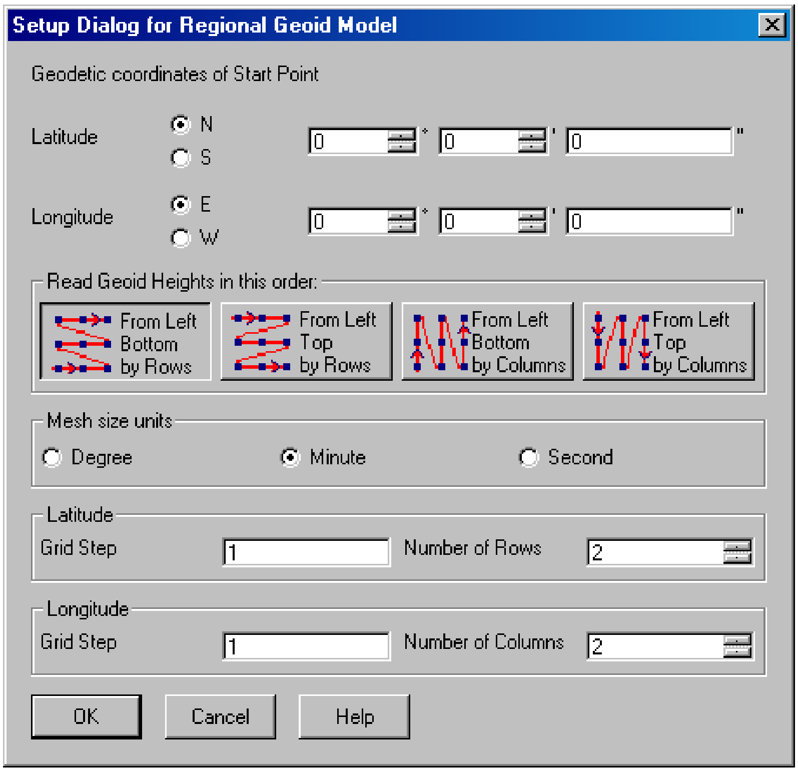


Figure 10-8

10.4. How to export a geoid model

If the user plans to use a geoid model, which has been imported into the current project from a text file, in some other projects, it is recommended to export this geoid model as a ***.jff*** file. This Pinnacle-specific file format provides the fastest import of geoid data into PINNACLE.

The ***'Export…'*** button allows the user to export a selected geoid model as a ***.jff*** file.

Pressing this button will invoke the standard '*File|Save As'* dialog box:

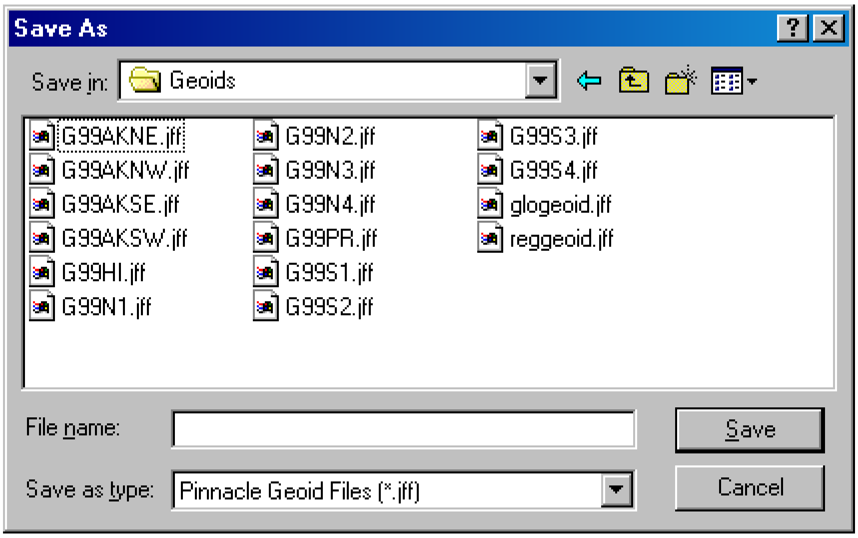


Figure 10-9

The user will need to enter the desired geoid file file name and press ***'Save'***.

When a regional geoid model is exported, the following dialog window appears:

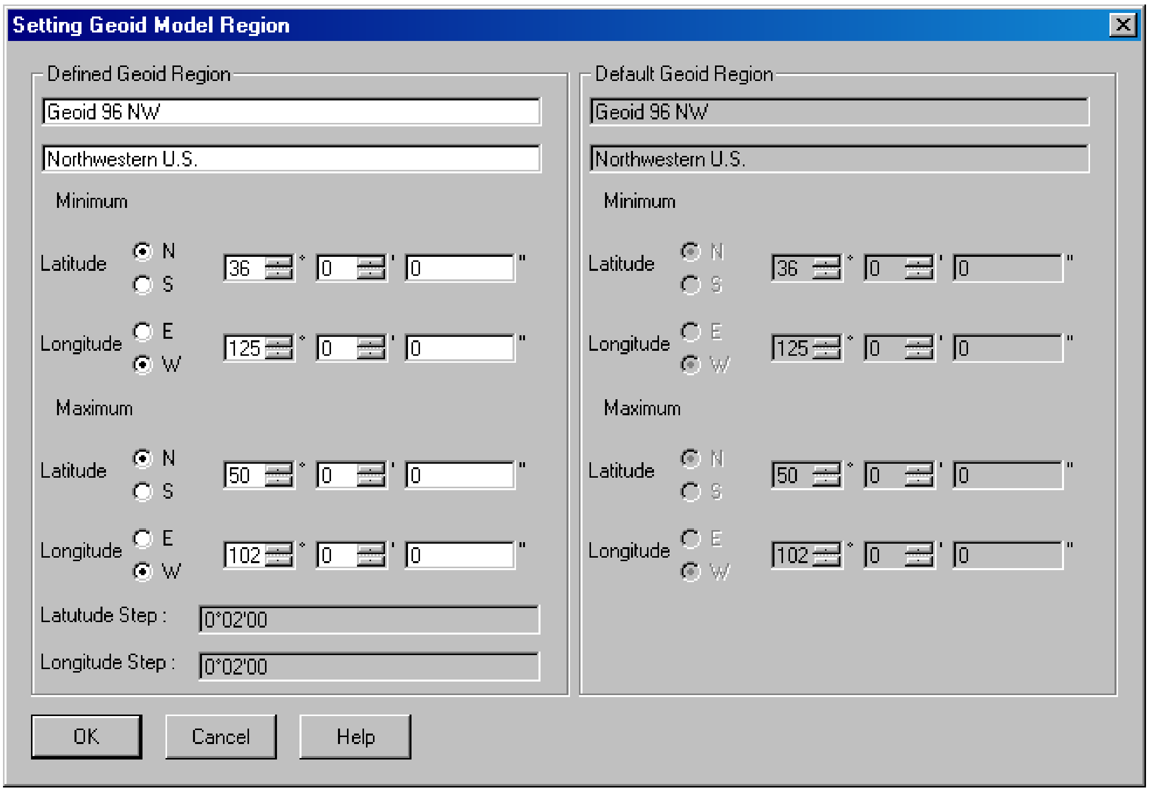


Figure 10-10

This window allows the user to rename the geoid, update the comments and/or narrow the applicability region.

10.5. How to create a local geoid model

The goal of the user creating a local model is to provide an accurate conversion between ellipsoidal and orthometric heights for the survey areas where it is impossible to effectively employ any existing geoid models. E.g., when there are no regional models for the area of interest, and global models do not provide the necessary reliability and precision.

Note that such geoid models may have significant systematic height errors (up to several meters or even larger). For this reason local geoid models are normally used only after a constrained adjustment has been performed to obtain the orthometric heights of the subnet's *non-control* points. It is strongly recommended *not to use* local geoid models with *Height Calculator* since it may result in very poor levels of accuracy.

To create a local geoid model for a subnet, the user must take the following steps:

- Perform for the given subnet all of the pre-adjustment tests relevant for free adjustment (see [2])
- Perform an *inner-constrained* (i.e. free) adjustment of the subnet (see [2]). This step is required to ensure that this subnet is free of blunders, etc.
- Select some points in the subnet and attach necessary vertical control (orthometric heights) to them. It can be achieved by using the '*Attach Control Point'* command from the subnet's context menu (see [1] and [2])

- Run the '*Control tie analysis'* test for the subnet (see [2])
- Perform an *inner- constrained* adjustment of the subnet once again
- Select the '*Save As Local Geoid'* command from the subnet's context menu

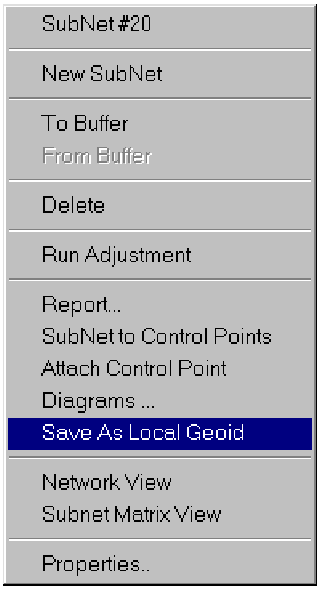


Figure 10-11

For the points with the attached vertical control, their geoid heights (also referred to as *geoid undulations*) will be calculated as differences between the ellipsoidal and orthometric heights. These data will then be saved to the database as a local geoid model (see [2]).

- Enter the new geoid model' name in the following dialog window

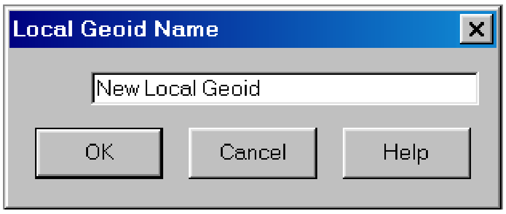


Figure 10-12

- Edit the newly created local model, i.e., search for possible outliers, which may be due to errors both in the measured ellipsoidal heights and in the vertical control, and reject them if any.

The quality of a local geoid model will depend on the following factors:

- o Accuracy of GNSS-measured ellipsoidal heights.

  Note. Only their *relative* accuracy is of importance. A *common* uncertainty (e.g., a constant bias brought about in the ellipsoidal heights because of the use of rough point positions when performing a free subnet adjustment) will not adversely affect the resulting accuracy
- o Accuracy of vertical control used;
- o Density and geometrical distribution of the points included in the local model.

  Note that the quality of vertical control is the fundamental precondition for obtaining a quality local geoid model.

It should also be noted that such "inadvertent errors" as incorrectly entered antenna heights or inaccuracies and typos in height control data can bring about errors in the local geoid model. Since *all* of the points of the local model are used when interpolating geoid heights to GNSS survey points, errors may grossly distort the geoid representation for the area of interest.

Another critical factor for deriving a quality local geoid model is the density and geometry (distribution) of the local model's points within the area of interest. Generally speaking, the more vertical control points are used and the more uniform their distribution over the survey area, the higher the quality of the interpolation and the easier it is to search for errors. Points for which geoid heights are interpolated should be situated within (or at least not far away from) the perimeter formed by the local model points.

For areas with a fairly smooth relief, a local model's points should not be spaced by more than 5-10 km apart.

Note that the total number of points in a local geoid model should not be less than five. Once a geoid model is created, it is automatically added to the geoid model list.

10.6. How to edit a geoid model

The ***'Edit…'*** button is used to edit geoid models from the '*Geoids'* list.

For global and regional models, only their names and comments can be edited.

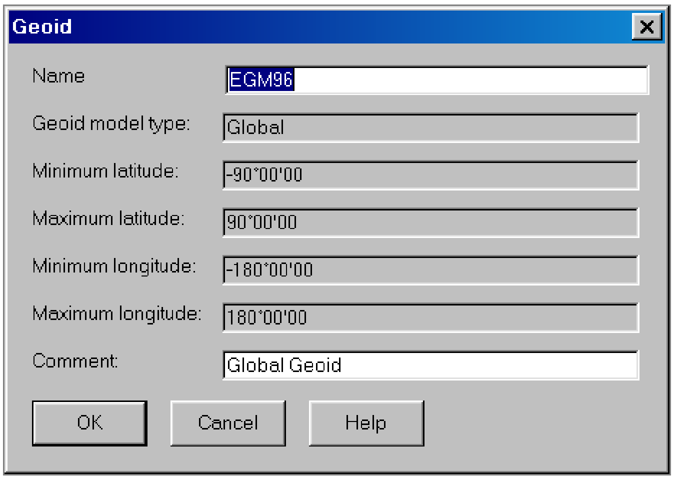


Figure 10-13

For local models, the following properties can be edited:

- Model name
- Geoid heights
- Geoid heights' rms errors
- Comment

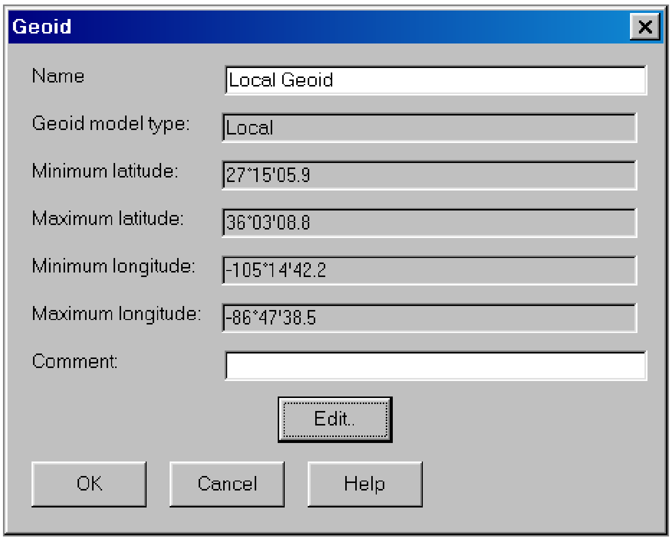


Figure 10-14

Press the ***'Edit…'*** button at the '*Geoid'* dialog window's bottom to start editing the local geoid's parameters (properties).

The following dialog window will appear (see Figure 10-15):

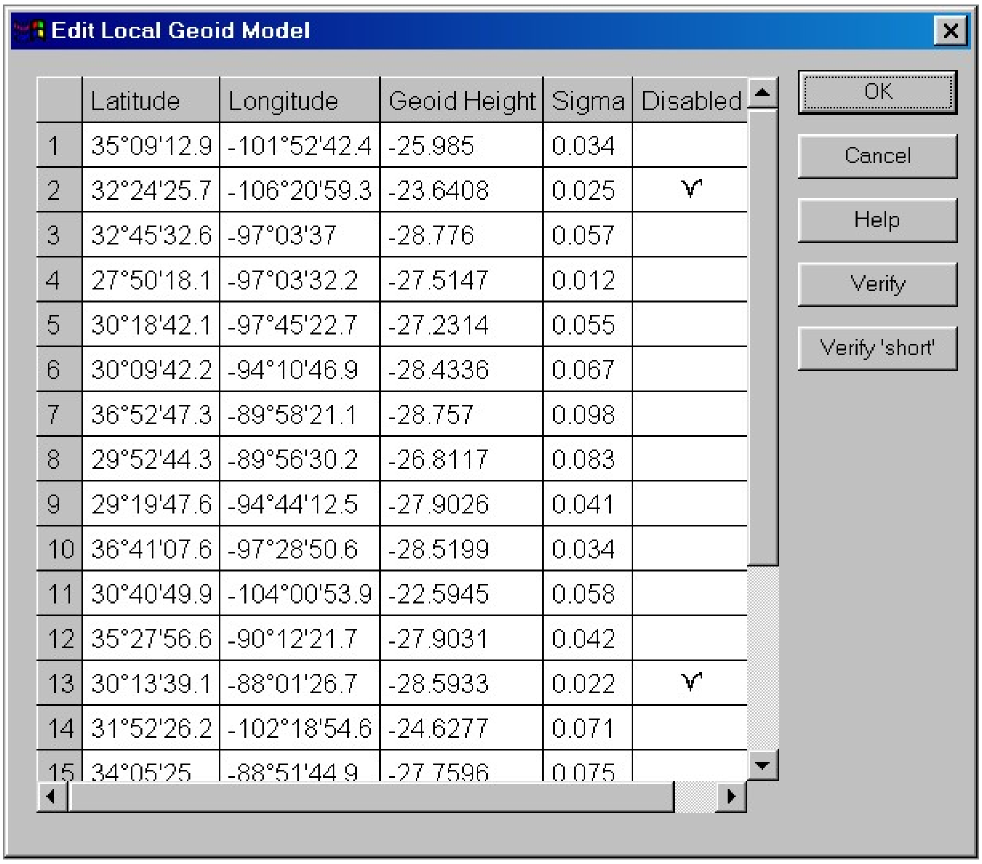


Figure 10-15

The user can disable some of the local geoid model's points if required. It can be done by double clicking in the '*Disabled'* field for the corresponding points. The user will see the checkmarks appear in this column as shown in Figure 10-15 for points 2 and 13.

The user must keep in mind, when disabling some points in a local geoid model, that the total number of the remaining points must not drop below five.

Note that if at least one of a local geoid's points has a zero rms error (or if this error is not specified for this point), all of the model's points will be assumed to have zero rms errors (whether there exist any non-zero rms errors in the '*Sigma'* column).

To check a local geoid model's quality, the following two tests are carried out:

1. In the first test, the largest errors are detected by means of the analysis of the "geoid slope". Geoid slope is calculated for a pair of points belonging to the given local model. The height difference computed is then compared against a predefined threshold (tolerance). For example, this approach will allow the user to identify a 1.5-meter antenna height error for a pair of points lying up to 4.0 km apart (such errors, when the user "forgets" to set the right antenna height, are not infrequent).
2. The second test is a finer tool for detecting erroneous data. It works effectively after all larger errors have been removed with the first test.

   In the second test, the program successively checks all the points in the model, one by one. Every point is "temporarily removed" from the model so that its geoid height is extrapolated using all the others. Then the value extrapolated is compared to the geoid height observed, and the corresponding *residual* is computed.

The ***'Verify'*** and ***'Verify short'*** options are used for verifying the quality of the created local geoid model. Pressing either button will bring in a '*Geoid Verify Log'* dialog window.

If the first test fails, the user will see a '*Geoid Verify Log'* window where the detected 'bad' pairs of points and their residuals are displayed (see Figure 10-16). For the pairs shown in this window the computed geoid slopes are found to exceed the a priori threshold value.

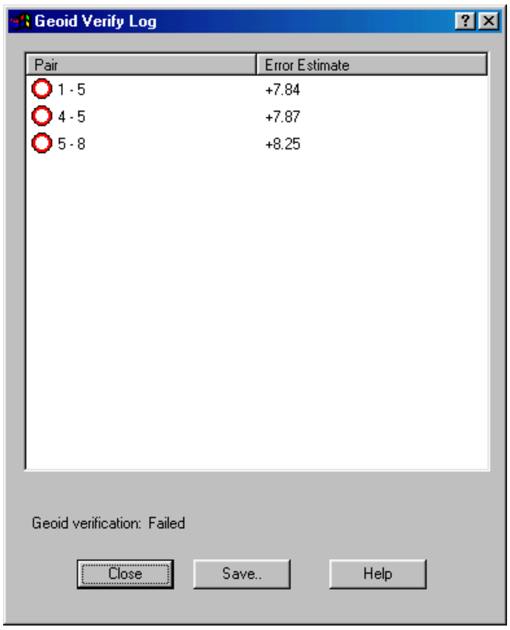
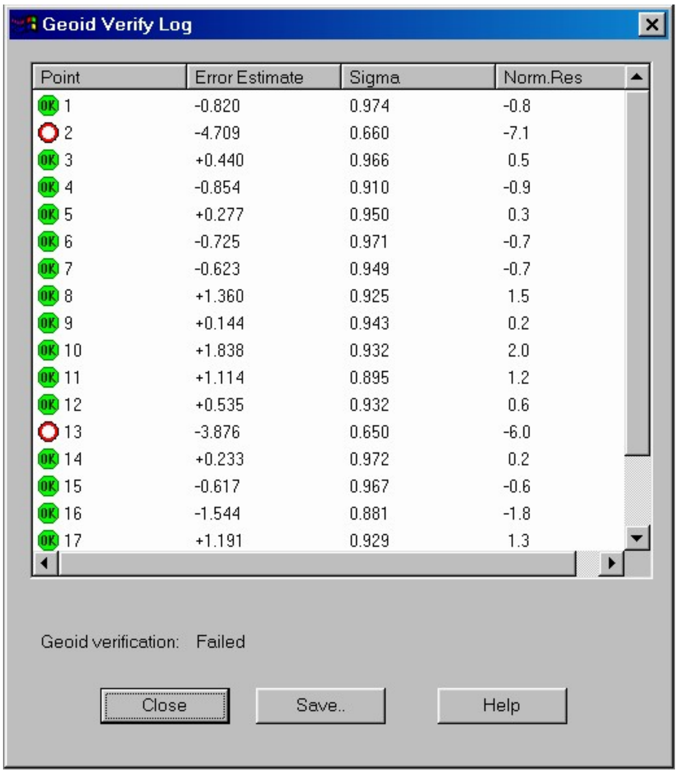


Figure 10-16

Note that the second test will not start if the first test is not passed.
If the first test is successfully passed, then the second test is run immediately . In this case the '*Geoid Verify Log*' window will show (see Figure 10-17):

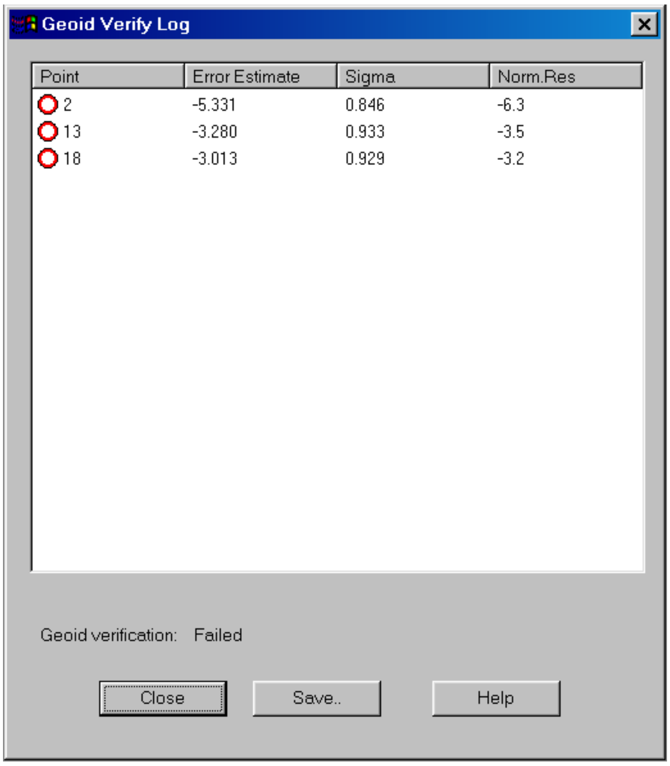
- o Which of the model's points are good (these are marked with OK) and which are bad (these are marked with O)
- o Height residuals ("Error estimate")
- o Rms errors ("Sigma")
- o Normalized height residuals ("Norm. Res")



Point	Error Estimate	Sigma	Norm.Res
OK 1	-0.820	0.974	-0.8
2	-4.709	0.660	-7.1
OK 3	+0.440	0.966	0.5
OK 4	-0.854	0.910	-0.9
OK 5	+0.277	0.950	0.3
OK 6	-0.725	0.971	-0.7
OK 7	-0.623	0.949	-0.7
OK 8	+1.360	0.925	1.5
OK 9	+0.144	0.943	0.2
OK 10	+1.838	0.932	2.0
OK 11	+1.114	0.895	1.2
OK 12	+0.535	0.932	0.6
13	-3.876	0.650	-6.0
OK 14	+0.233	0.972	0.2
OK 15	-0.617	0.967	-0.6
OK 16	-1.544	0.881	-1.8
OK 17	+1.191	0.929	1.3

Figure 10-17

If the user presses the ***Verify 'short'*** button instead of '***Verify***', the '***Geoid Verify Log***' window will display only the 'bad' points, i.e. the points whose normalized residuals do not meet the "*3 sigma*" criterion (i.e. their magnitudes are larger than 3.0, see Figure 10-18).



Point	Error Estimate	Sigma	Norm.Res
2	-5.331	0.846	-6.3
13	-3.280	0.933	-3.5
18	-3.013	0.929	-3.2

Figure 10-18

A large residual or normalized residual for a point may indicate that:

- This point's geoid height is erroneous;
- This point is good, but there is one, or more than one, adjacent point whose geoid heights are erroneous. Those points have adversely affected the given point;
- The given point is *ill-located*, which results in a big interpolation error (this is the case when a point lies far from the other points of the local model)

Having analyzed these data, the user determines which points should be excluded from the local model, which points should be downweighted, and which may be retained as they are.

The best editing strategy is as follows:

- Reject a suspicious point
- Estimate how the residuals of the rest of the points will change (taking into account the configuration of those points). If the new residuals are considerably smaller than the original ones, this indicates that the rejected point is erroneous .

This procedure allows the user to detect some 10-20 cm errors in geoid heights depending on the particular geometry and density of points in a local model.

The user can save *Geoid Verify Log* as a text file by using the '***Save'*** button.

Pressing this button will invoke the standard '*File|Save As'* dialog box as shown in the example in Figure 10-19.

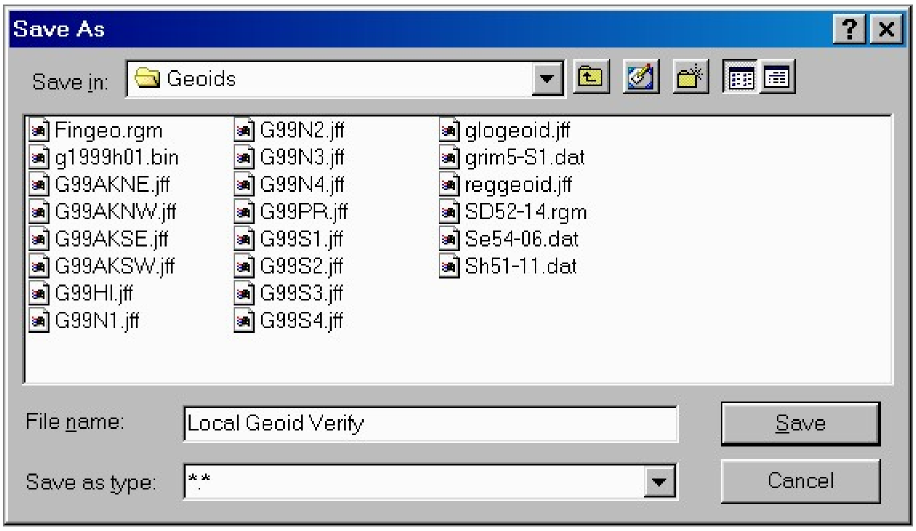


Figure 10-19

10.7. How to delete a geoid model

The ***'Delete'*** button allows the user to remove unnecessary geoids from the '*Geoid Models'* list.

Select an unnecessary geoid in the '*Geoid Models'* list and press the ***'Delete'*** button. After pressing this button, the selected geoid will be immediately (without any warnings or confirmation prompts!) deleted from the '*Geoid Models'* list.

11. *References*

[1]. PINNACLE Reference Documentation Suite. Control Data Lists. August 2001.
[2]. PINNACLE Reference Documentation Suite. Network Adjustment. July 2001.

TOPCON
POSITIONING SYSTEMS

Pinnacle™
Reference Documentation Suite

EVENT EDITOR

User's Manual

This documentation reflects
the April 4, 2001 version
of Pinnacle 1.0

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USER'S NOTICE

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Pinnacle's Event Editor

1. Introduction

In addition to GPS-controlled survey flight navigation, GPS is also widely used for high precision camera positioning in photogrammetric applications.

There are two main aerial photography modes depending on the way the photo camera is mounted on the aircraft.

Mode #1: aerial photography using gyro-stabilized camera mounts

In this mode, the camera film plane will be parallel to the local horizon plane irrespective of the aircraft's drift, pitch and roll (assuming these angles will vary within some pre-defined limits, which are gyro mount specific.) As the gyro mount's sensors measure the camera's orientation angles in an aircraft-fixed coordinate system, the recording unit will record the angles measured at the time of exposure.

Mode #2: aerial photography without gyro-stabilized camera mounts

In this mode, the plane of the camera film is, generally speaking, freely oriented relative to the local horizon plane. The attitude of the aircraft with respect to the Earth will be determined by means of the on-board navigation equipment. In addition, the camera's orientation angles in the aircraft-fixed coordinate system will be measured and recorded.

At the pre-flight stage the user should measure the offsets (*Xoffset*, *Yoffset*, *Zoffset*) between the camera's center of rotation (pivot point) and the antenna phase center. Also the distance from the camera's center of rotation to the film plane is measured (see Figure 1). During the flight the length $Roffset = \sqrt{Xoffset^2 + Yoffset^2 + Zoffset^2}$ of the vector offset will remain constant but the projection ($Roffset_N$, $Roffset_E$, $Roffset_H$) of the vector offset onto the local horizon plane will change as the aircraft's drift, pitch, roll and heading are changing.

The ***Event Editor*** module is designed to compute the position of the camera's perspective center.

Initial data:

1. Coordinates of the antenna phase center in WGS84, obtained by processing the flight trajectory with Pinnacle's *Kinematic Engine*.
2. Camera exposure time**.** Note that the Event Editor allows the user to enter *time corrections* necessary for the program to recalculate the event time tags into GPS time.
3. Offsets from the camera's center of rotation to the antenna phase center. Distance from the camera's center of rotation to the film plane. The focal length of the camera.
4. Orientation angles (drift, pitch and roll) as required for the selected camera installation mode:

   #1 "with gyro" – the **camera**'s drift, pitch and roll in the local (a.k.a. topocentric) coordinate system,

   #2 "without gyro" – the **aircraft**'s drift, pitch and roll in the topocentric coordinate system *plus* the **camera**'s drift, pitch and roll in the aircraft-fixed coordinate system.

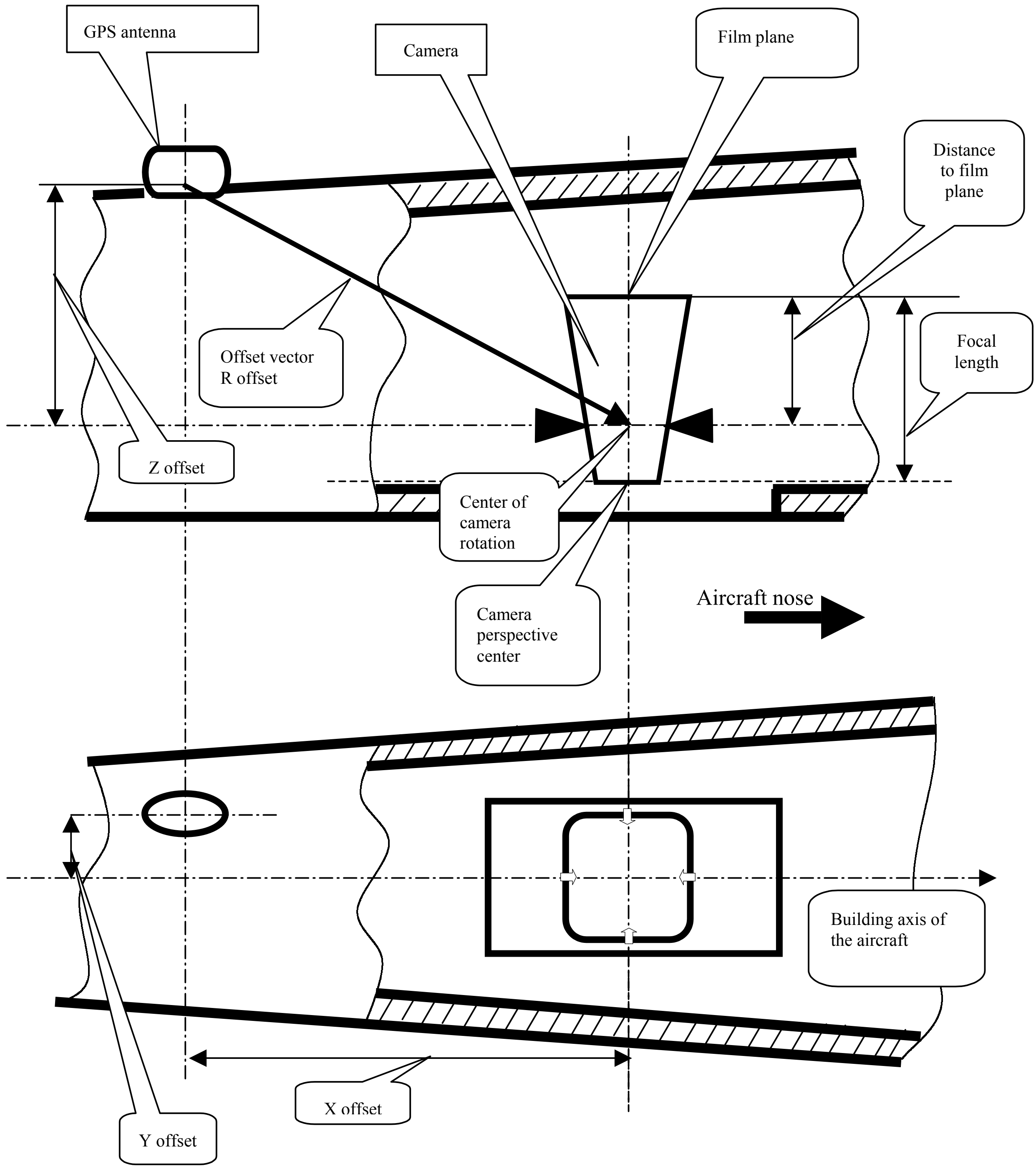


Figure 1. GPS antenna and photo camera mounted on the fuselage

The program first interpolates the coordinates of the antenna phase center to the event reception times and then calculates, by using the measured orientation angles and reducing the position of the antenna to the position of the camera, the coordinates of the camera's perspective center at the time of exposure.

The coordinates should be calculated for the exposure time T_{exp} (the exact time of the photograph), which is defined as the middle point of the corresponding exposure interval. To reference the event time to the middle point T_{exp} of the exposure interval, the **Delay interval** should be taken into account (see Figure 3.)

2. *Event Editor* and *Parameters of Events*

In the ***Solution*** panel, right-click on the desired Fan in the ***Fans*** tree and select ***Event Editor*** from the pop-up menu.

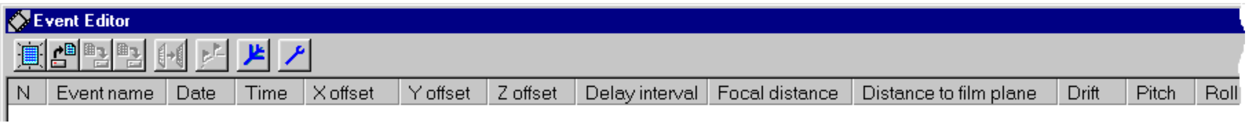


Figure 2. ***Event Editor*** window

A blank table with the following parameters will appear:

2.1. N – event number.

Icons next to the event numbers have the following meanings:

 - coordinates are available (calculated) for the event,

 - coordinates for the event are not calculated due to insufficient GPS measurements and/or erroneous initial data,

 - coordinates for the event are unavailable because the user has aborted interpolation,

 - coordinates for the event are unavailable because the user has disabled this event.

2.2. Event name – name of the event

2.3. Date – date of the event

2.4. Time – event time

To synchronize the operation of GPS receiver and camera, the camera electric pulse (TTL level) is applied to the input of the receiver's external event detector (see Figure 3).

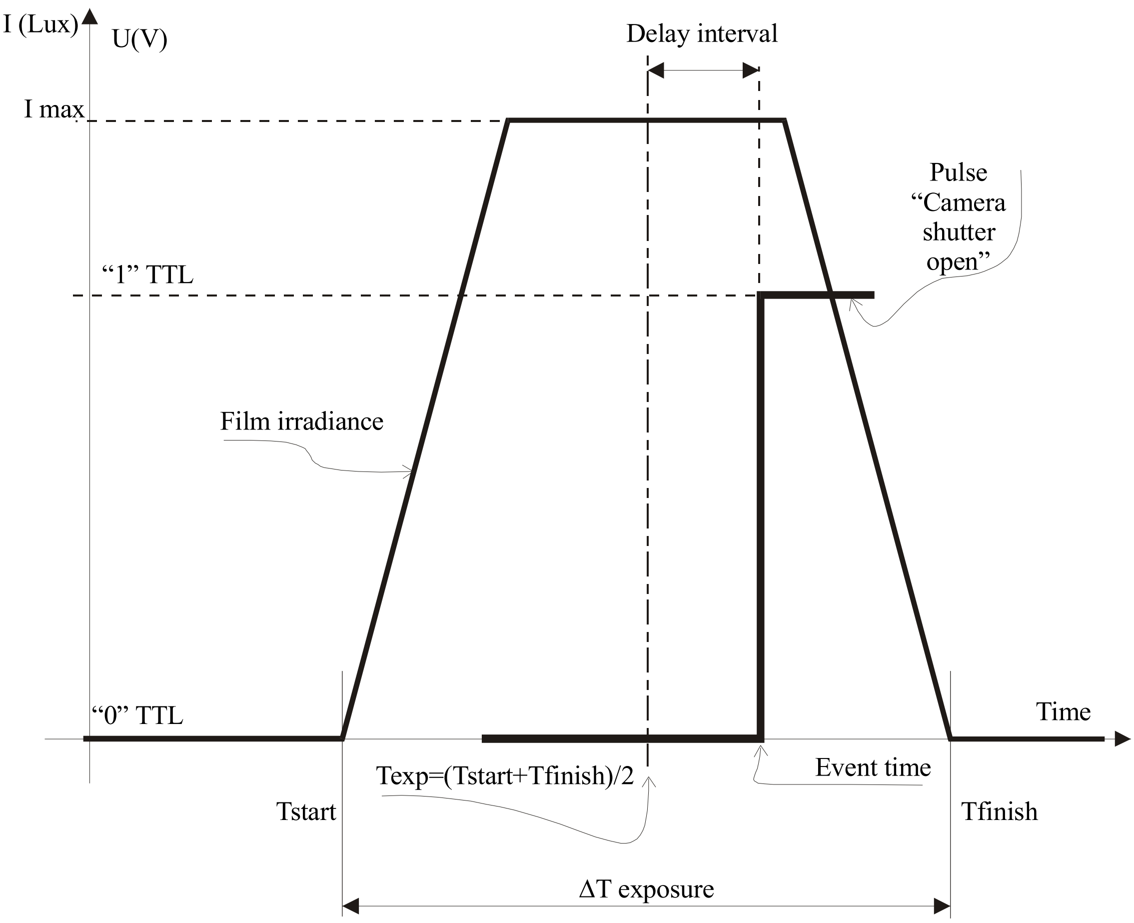


Figure 3. Event time and **Delay interval**

Usually the event reception time does not coincide with the receiver measurement time (“epoch”) (see Figure 4).

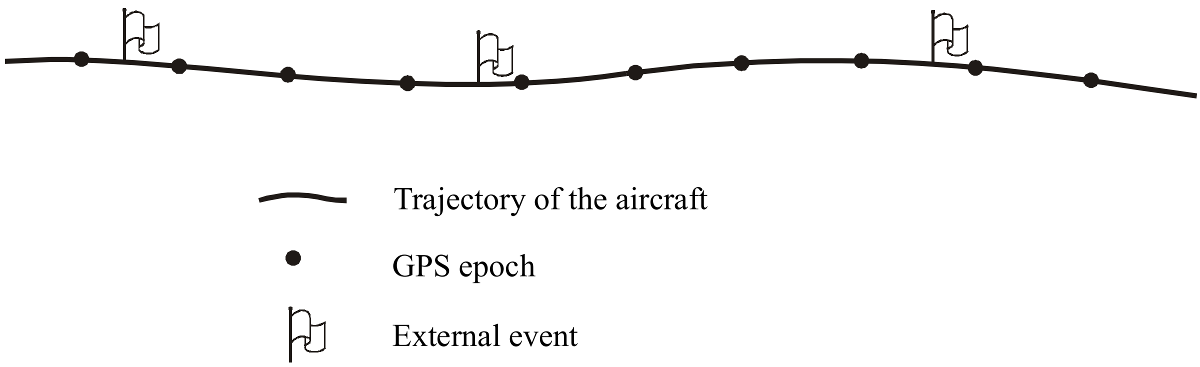


Figure 4. Events and GPS epochs

2.5. X offset (m)

The X offset is measured along the “building axis” of the aircraft from the antenna phase center to the camera’s center of rotation (see Figure 1).

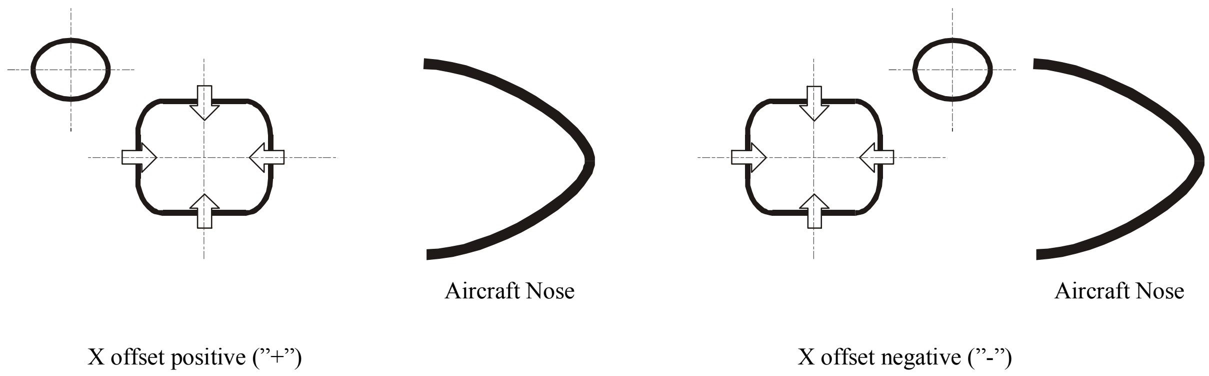


Figure 5. Signs of **X offset**

2.6. Y offset (m)

The Y offset is measured across the "building axis" of the aircraft towards the aircraft's wings from the antenna phase center to the camera's center of rotation (see Figure 1).

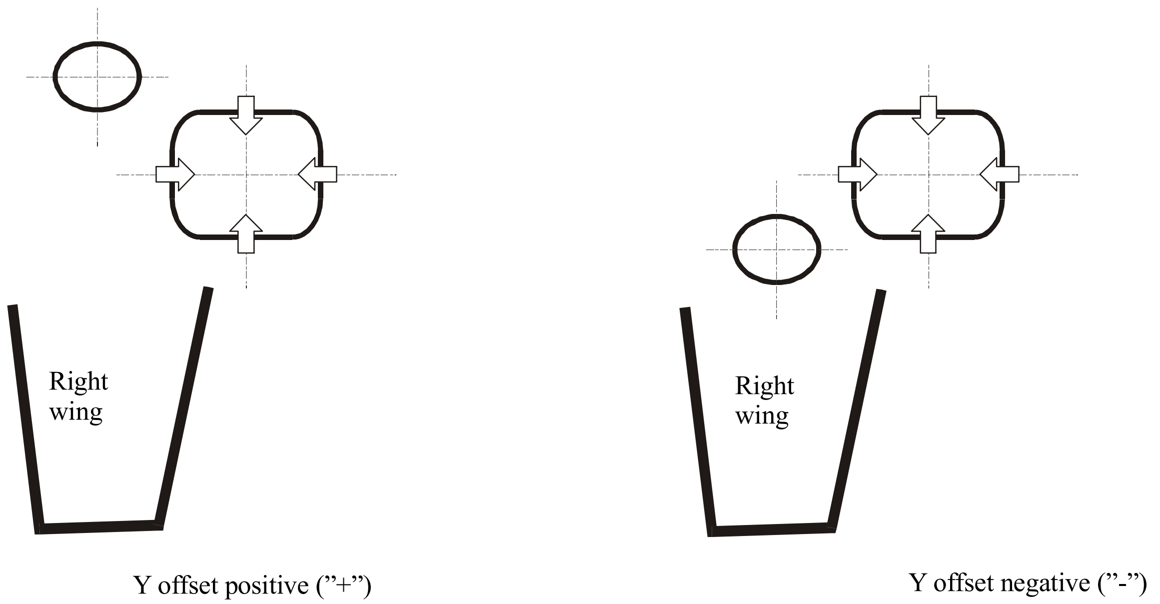


Figure 6. Signs of **Y offset**

2.7. Z offset (m)

The Z offset is measured along the vertical axis going through the top of the aircraft's fuselage from the antenna phase center to the camera's center of rotation (see Figure 1). The offset will be **negative ("-")** if the camera is located below the antenna.

2.8. Delay Interval (s)

The **Delay Interval** is the time offset between the instant when the camera's pulse goes off (this time is measured by the event detector and recorded into the log file) and the middle point T_{exp} of the exposure interval. In addition, the **Delay Interval** parameter can be used to account for some other time offsets, such as the shift between the time scale in which events are recorded and that selected for raw data measurements. If the time that the camera pulse goes off precedes the middle point T_{exp} of the exposure interval (as it is shown in Figure 3), the **Delay Interval** will be negative ("–"). Otherwise, the **Delay Interval** will be positive ("+").

2.9. Focal distance

Focal distance is the focal length of the camera lens.

2.10. Distance to film plane

The distance to the film plane is measured from the camera's center of rotation to the film plane. The distance will be **positive ("+")** if the camera's center of rotation is located below the film plane (see Figure 1.)

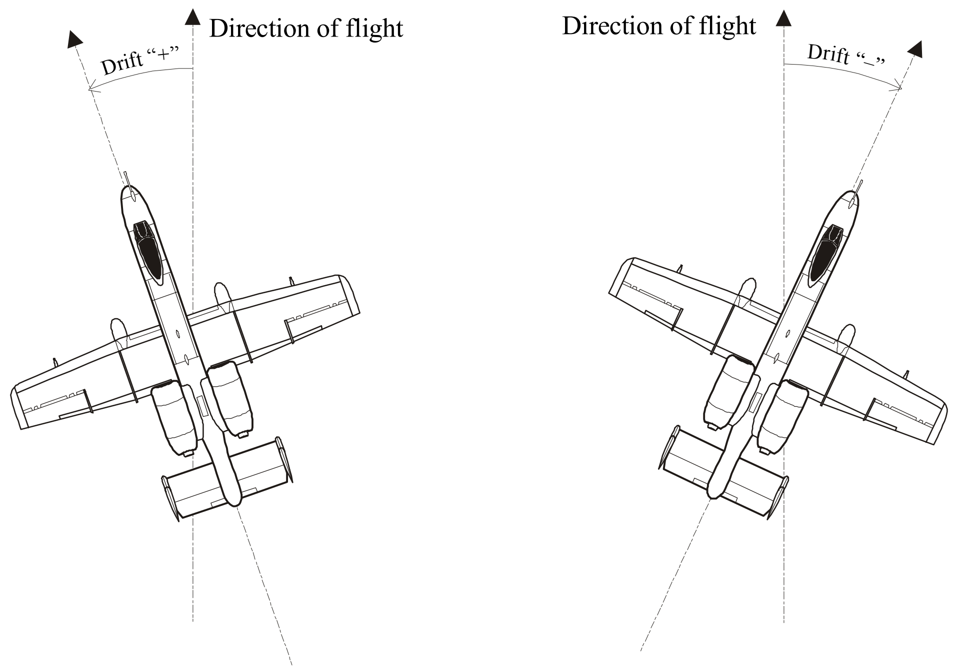
2.11. Aircraft Drift –Pitch - Roll

Aircraft orientation angles (attitude) in the local (topocentric) coordinate system are defined as drift, pitch and roll. These angles are read in from the aircraft's navigational devices at the instant of fixing the camera pulse (event time).

Note. *Event Editor* enables the use of the aircraft's orientation angles (**Drift, Pitch, Roll**) only when **Mode #2** ("without gyro") is selected. In this mode, the *Airplane parameters/Gyro mount* checkbox is unchecked.

2.11.1. Drift

Drift is defined as the angle between the projections of the aircraft's building axis and its velocity vector onto the local horizon plane.



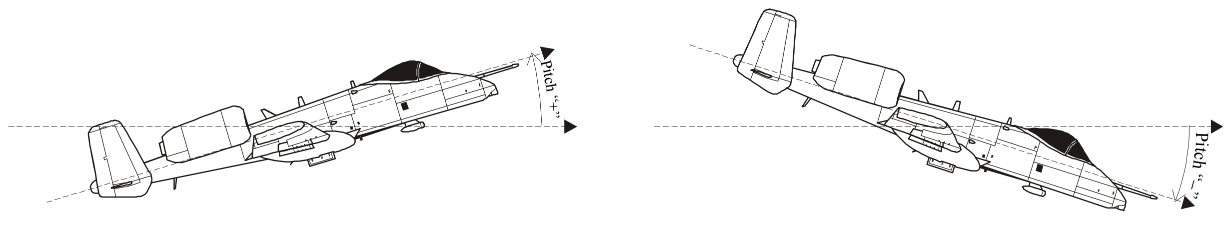
Drift is positive if the aircraft nose points to the left of the flight direction (”right wing forward”.)

Drift is negative if the aircraft nose points to the right of the flight direction (”left wing forward”.)

Figure 7. Signs of **Drift**

2.11.2. Pitch

Pitch is defined as the angle between the building axis of the aircraft and the local horizon plane.



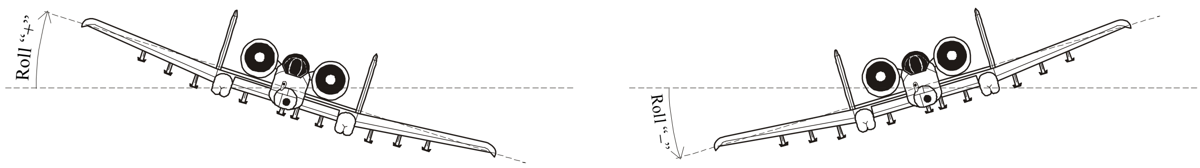
Pitch is positive (”+”) if the aircraft nose is above the local horizon plane (”nose up”.)

Pitch is negative (”–”) if the aircraft nose is below the local horizon plane (”nose down”.)

Figure 8. Signs of **Pitch**

2.11.3. Roll

Roll is defined as the angle between the aircraft’s right wing and the local horizon plane.



Roll is positive if the aircraft right wing is above the local horizon ("right wing up".)

Roll is negative if the aircraft right wing is below the local horizon ("right wing down".)

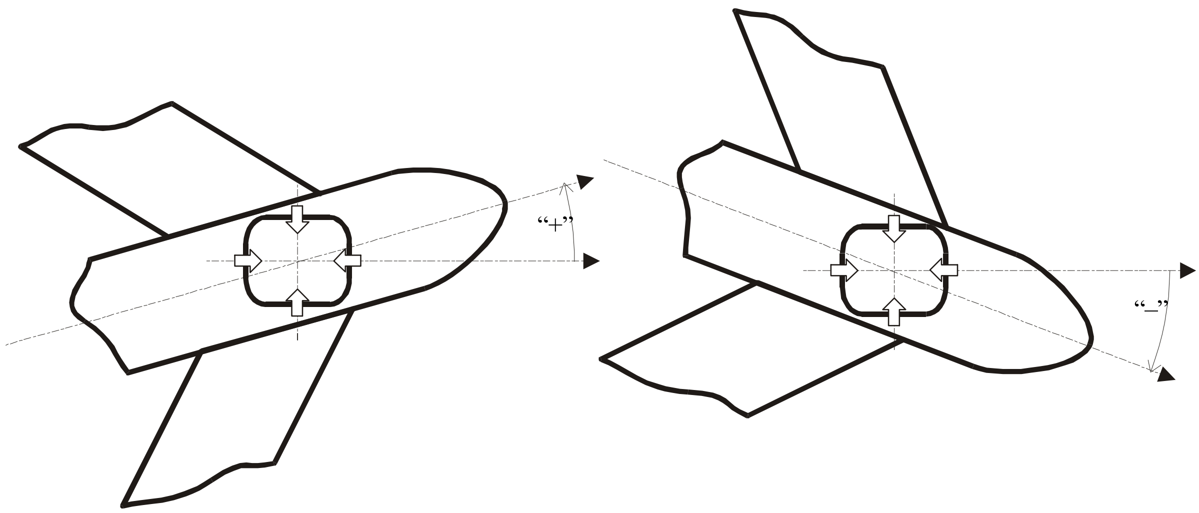
Figure 9. Signs of **Roll**

2.12. Camera Drift -Pitch -Roll

Orientation angles of the camera determined in the aircraft-fixed coordinate system are defined as camera drift, pitch and roll. These angles are measured at the time the camera's shutter goes off.

2.12.1. Drift of camera

Drift of the camera is defined as the angle between the projection of the aircraft's building axis onto the film plane and the axis going through the coordinate marks of the camera frame.



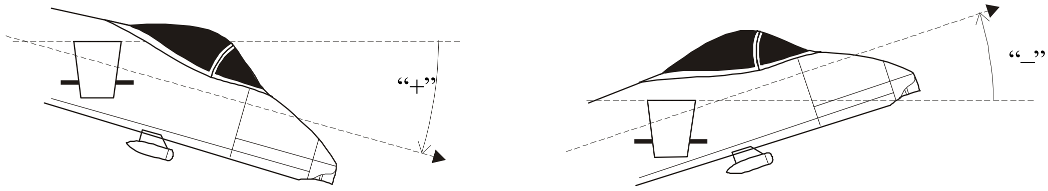
Drift of camera is positive if camera's front is directed to the right of aircraft

Drift of camera is negative if camera's front is directed to the leftt of aircraft

Figure 10. Signs of **Drift of Camera**

2.12.2. Pitch of camera

Pitch of the camera is defined as the angle between the film plane and the aircraft's building axis.



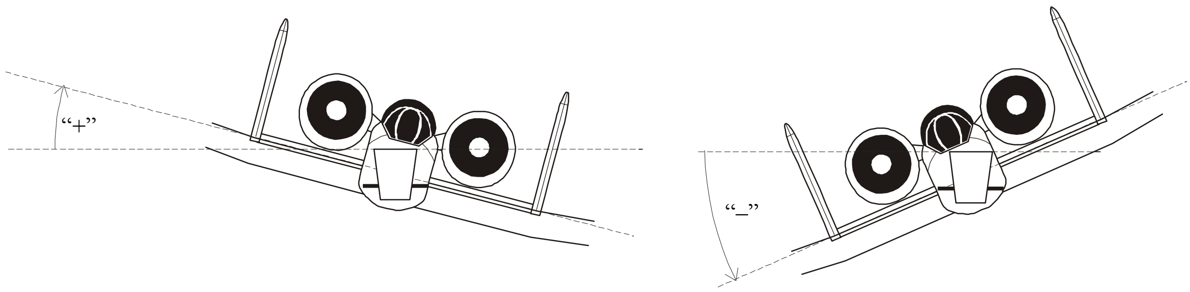
Pitch of camera is positive if airplane nose is below the film plane.

Pitch of camera is negative if airplane nose is above the film plane.

Figure 11. Signs of **Pitch of camera**

2.12.3. Camera Roll

Camera roll is defined as the angle between the film plane and the plane going through the aircraft's wings.



Roll of camera is positive if the right wing is above the film plane.

Roll of camera is negative if the right wing is below the film plane.

Figure 12. Signs of **Roll of camera**

2.13. Status

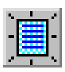
Status will show an event's coordinates or explain why they may be unavailable.

2.14. X result / Y result / Z result

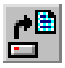
The coordinates of the camera's perspective center in WGS84 are given as X result, Y result and Z result.

3. Buttons on the Event Editor toolbar

3.1. New

Press  to clear the current table (you will be prompted to first save the changes made).

3.2. Open

Press  to load an event file into ***Event Editor***. If the corresponding kinematic trajectory (*Fan*) is already processed, coordinates associated with the events will be **automatically calculated** while importing the event file.

Event Editor can import the following file formats:

- Ashtech® PhotoDat File (*.dat)
- TPS Photo Event File (*.evt)
- ASCOT® Event File (*.ev*)

TPS receivers have two external event detectors to receive event signals and "record" them into the current log file (*.jps format). The first detector handles *XA event signals* and puts corrresponding *XA event records* in the receiver's log file. The other event detector processes *XB event signals* exactly in the same manner. If at least one *XA event record* and/or one *XB event record* is found in the raw data file (*.jps) imported to Pinnacle, *external event files* NAME.XA.dat and/or NAME.XB.dat will be created in the current project's directory. In this file naming convention, NAME stands for the name of the *.jps-file imported and the affix XA or XB indicates the event signal type.

An example TPS event file.

```
ROV_ 2 09:34:03.5647382
ROV_ 2 09:34:06.6649699
ROV_ 2 09:34:09.6670275
```

Here

- `ROV_` is the name of the receiver's occupation at the event reception time,
- `2` is day of the GPS week, and
- `09:34:03.5647382` is time within that day.

You will notice that the format of TPS event file is similar to the format of Ashtech® *photo.dat* file.

Event Editor can also import ASCOT® event files in *.ev* format.

An example ASCOT® event file.

```
* Event input logging LEICA® MX9500 *

Date:   15.04.00
Ev#1: 07:34:41.5782   00110013   0178   -0.41    1.02    1.51
Ev#1: 07:34:44.0845   00110014   0179   -0.42    0.51    1.55
Ev#1: 07:34:46.8399   00110015   0180   -0.41    0.36    1.59
```

Here

`07:34:41.5782` - HH:MM:SS.SSSS – event time in GPS time scale.

`00110013` – the four left-hand-most digits specify the *flight line* number (`0011`) and the rest designates the *flight frame* number (`0013`).

`0178` – *sequential* number of the frame (it depends on the camera's internal shot counter);

`-0.41` – Pitch,

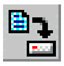
`1.02` – Roll,

`1.51` – Drift – orientation angles of the camera mounted on the gyro mount. When an Ascot event file is imported to Pinnacle, these angles are written into the **Pitch of camera/Roll of camera/Drift of camera** columns.

Note that after an event file[1] has been imported into ***Event Editor***, its contents can be saved as a **TPS Photo Event File** with the extension ***.evt***. The original event file (with the extention ***.dat*** or ***.ev****) will remain intact of course.

The format of **TPS Photo Event File** is described below (see the **Save** option.)

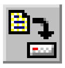
3.3. Save

Press  to save all events to a **TPS Photo Event File** (*.evt).

TPS Photo Event File stores parameters of the events, one line of text per event. Parameters are separated with commas.

The *Save* button is disabled (grayed-out) if no events are specified in the ***Event Editor*** or if no changes have been made since the last save.

3.4. Save as

Press  to save all events to file.

This command allows the user to save the events to a **TPS Photo Event File** (*.evt) or, alternatively, to generate a report in (*.erp) format containing both the event data and estimated accuracies (RMS errors). The program will prompt the user to select a coordinate system, datum and grid zone (if applicable).

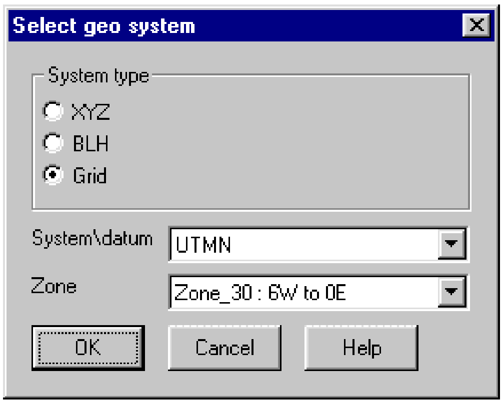


Figure 13. Selecting coordinate system for **TPS Photo Report**

Depending on the type of the selected coordinate system, the contents of the **TPS Photo Report** (*.erp) file will be written in one of the following three formats.

A) XYZ (Cartesian) coordinates

```
JP026PPERF *** Photo Events Report File ***

Geo system type: XYZ
```

[1]) regardless whether it is TPS, ASCOT® or Ashtech® event file format

```
Datum: WGS-84

Base Station - PIPE-9; X: 2964238.986362, Y: 2235536.111892, Z: 5170333.222299

#Event | Event name | Date and Time | X | Y | Z | RMS

1  00010001  15.04.00 07:04:26.516300000  2965036.789879     2234012.970854   5170564.097584   0.018294
2  00010002  15.04.00 07:04:29.172400000  2964887.926745     2234284.548570   5170563.461324   0.018310
3  00010003  15.04.00 07:04:31.578200000  2964793.450985     2234467.200070   5170564.075355   0.018325
```

B) BLH (Geodetic) coordinates

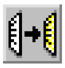
```
JP026PPERF *** Photo Events Report File ***

Geo system type: BLH
Datum: WGS84

Base Station - PIPE-9; Latitude: N54°30'13.98165", Longitude: E36°59'46.5768", Height: 1293.391316

#Event | Event name | Date and Time | Latitude | Longitude | Height | RMS

1  00010001  15.04.00 07:04:26.516300000  N54°30'13.5704"    E33°59'46.5813"  1292.686258      0.018294
2  00010002  15.04.00 07:04:29.172400000  N54°30'13.5661"    E34°0'1.8457"    1292.001191      0.018310
3  00010003  15.04.00 07:04:31.578200000  N54°30'13.6144"    E34°0'16.1132"   1291.688228      0.018325
```

C) NEU (Grid) coordinates

```
JP026PPERF *** Photo Events Report File ***

Geo system type: Grid
System name: UTMN
Zone name: Zone_37 : 36E to 42E

Base Station - PIPE-9; Northing: 6041433.742892, Easting: 370256.367831, Height:1293.391316

#Event | Event name | Date and Time | Northing | Easting | Height | RMS

1  00010001  15.04.00 07:04:26.516300000  6046954.934877     758707.229013    1292.686258      0.018294
2  00010002  15.04.00 07:04:29.172400000  6046970.719671     758986.981091    1292.001191      0.018310
3  00010003  15.04.00 07:04:31.578200000  6046986.709511     759241.350488    1291.688228      0.018325
```

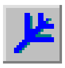
The save as button will be disabled (grayed-out) if no events are listed in ***Event Editor***.

3.5. Copy

Press  to copy the data from the selected rows to the Clipboard as tab-separated text (note that only the "set to visible" columns will be taken into account while copying)

The copy button will be disabled (grayed-out) if no events are selected in ***Event Editor***.

3.6. Airplane parameters

Press  to set up the parameters for the airborne GPS antenna and the photo camera mounted on the aircraft's fuselage. These parameters are supposed to be constant during the flight and *should not vary* from flight to flight. All corresponding settings are stored in an *airplane.jff* file and can be used to process data from other flights, if necessary.

This button allows the user to enter the following installation parameters:

1. Offsets (**Xoffset**, **Yoffset**, **Zoffset**) between the antenna phase center and the camera's center of rotation (meters)
2. **Delay interval** (seconds)
3. **Focal Distance** (meters)
4. **Distance to film plane** (meters)
5. Camera installation mode (with or without a gyro mount).

The user can create a new set of parameters or edit an existing one. The user can also delete a set or import an *airplane.jff* file containing other parameter sets.

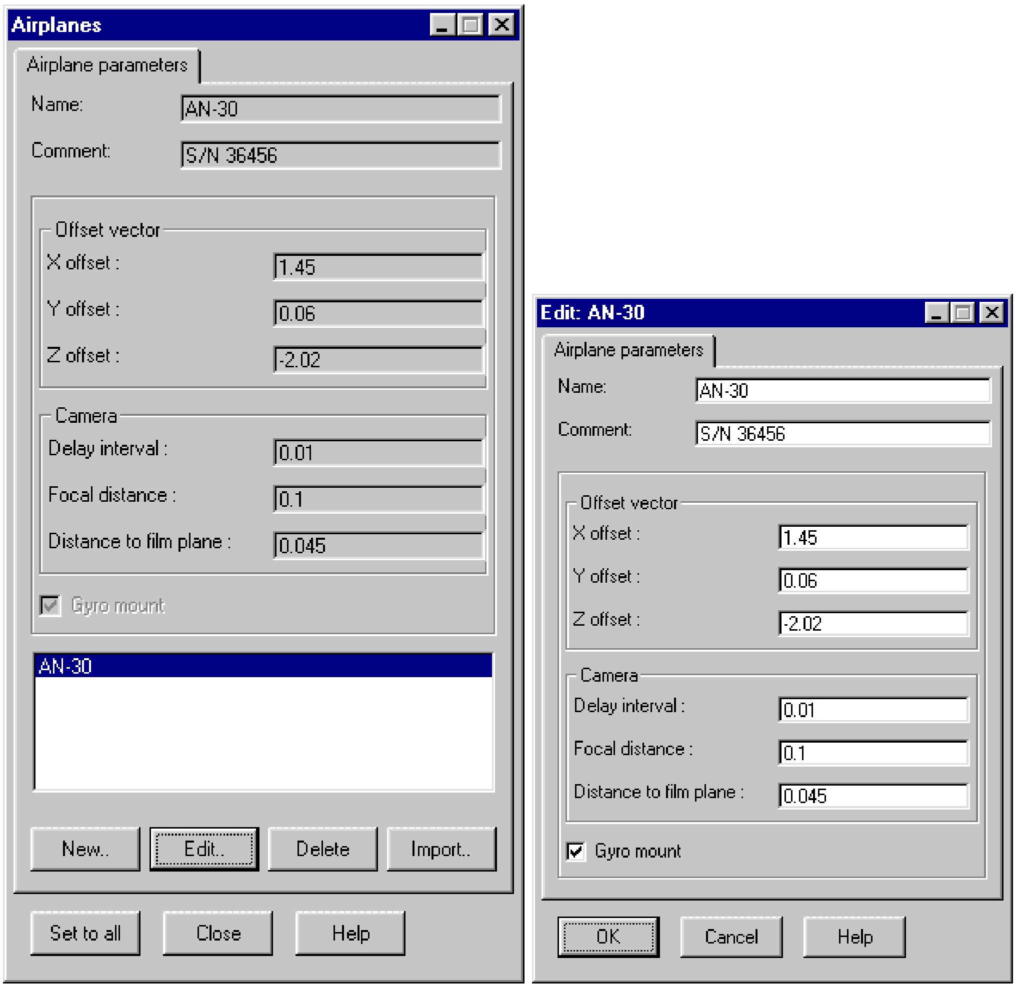
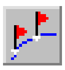


Figure 14. **Airplane parameters** dialog box

The **Set to all** button is used to assign the parameters associated with the selected airplane type to all of the events specified in the ***Event Editor*** window.

3.7. *Event intervals* plot

Press  to see the *event intervals* plot.

On this plot, the X-axis stands for the event time whereas the Y-axis shows the time difference (in seconds) between the current event and the previous one.

Different colors for points on the plot have the following meaning:

- × - coordinates for the event are available (calculated)
- × - coordinates for the event are unavailable due to insufficient raw data measurements or bad initial data,
- × - coordinates for the event are unavailable because interpolation was aborted by the user,
- × - coordinates for the event are not available because the user has disabled this event.

The *Event Intervals* plot allows the user to verify:

1) "Behavior" of the camera pulses over the whole flight time.

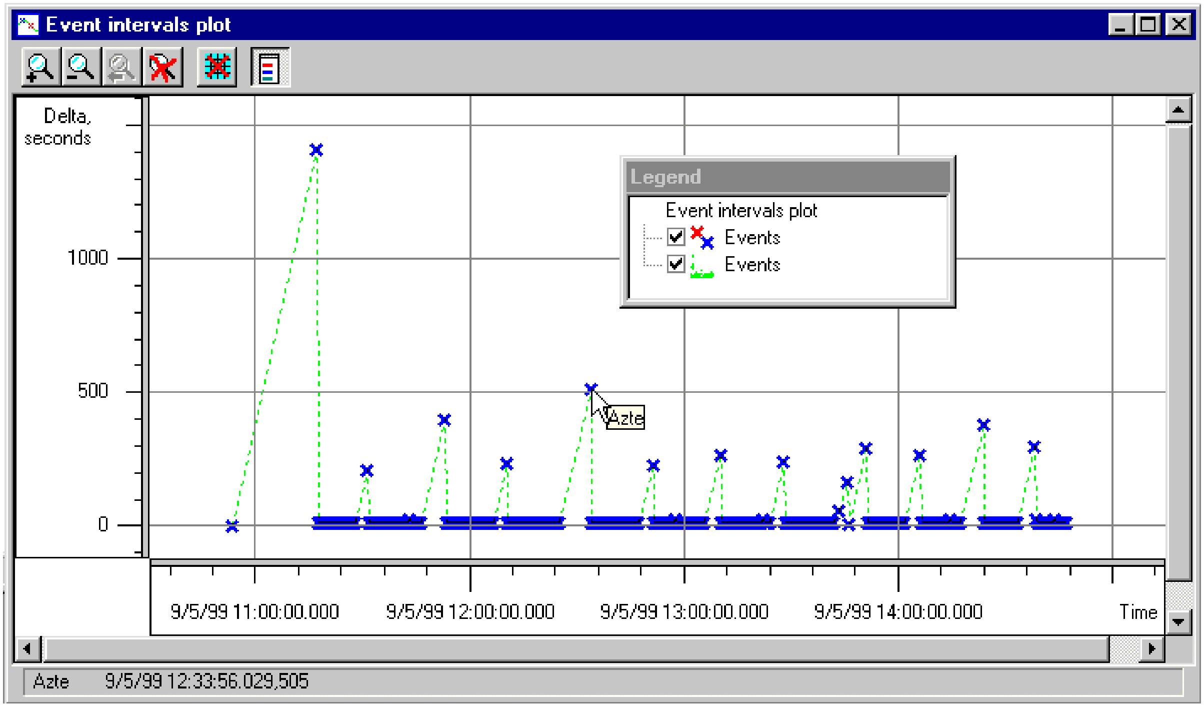


Figure 15. *Event Intervals* plot

2) Regularity and consistency of external pulses (isolating "false events").

To check data for "false events", you may need to use *zoom-in* when examining the plot. Recall that "false events" may be caused by blanks or interference (powering up the camera and the like). As a rule, one can easily tell "false" events from the true ones visually: the latter have a regular pattern on the plot whereas the former look like "outliers".

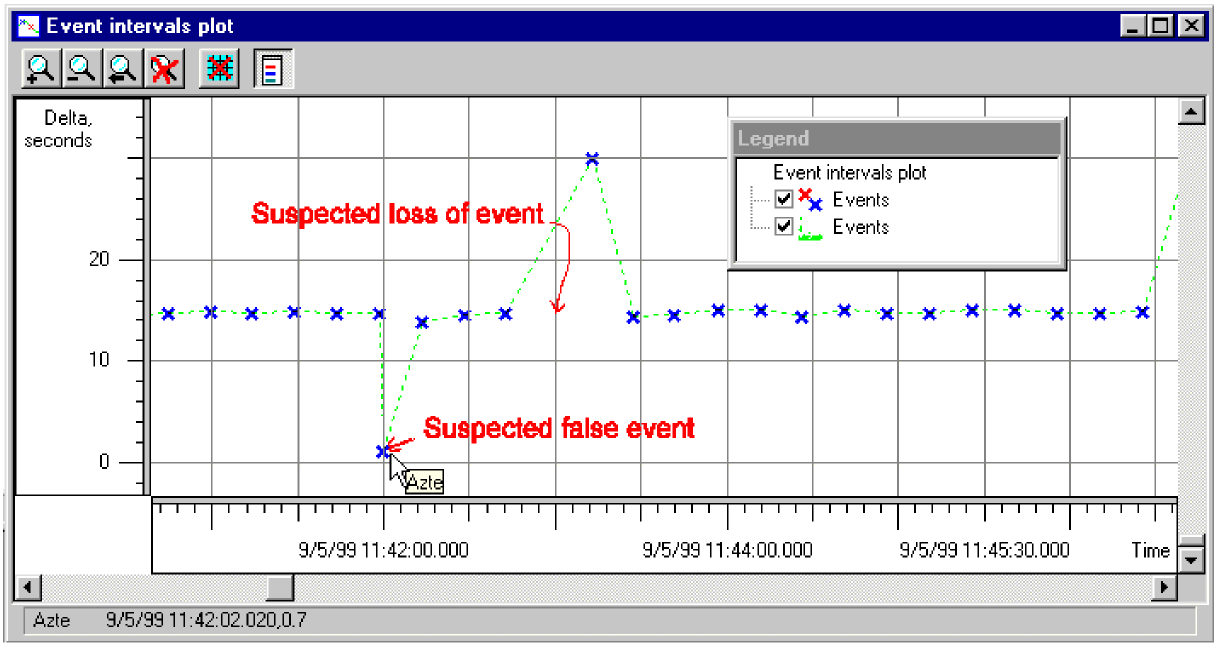
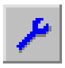


Figure 16. Using the *Event intervals* plot to detect false events

The button will be disabled (grayed-out) if no events are listed in ***Event Editor***.

3.8. Event Editor's Properties

Press  to select *active* columns for Event Editor's main window and to set up the required interpolation parameters. Columns set to *active* will be visible in the main window; the other columns, which are called *hidden*, will not be shown on the screen.

The ***Columns*** tab will allow the user to toggle columns to be active or hidden. To show or hide the columns, highlight the columns you need and use the arrows.

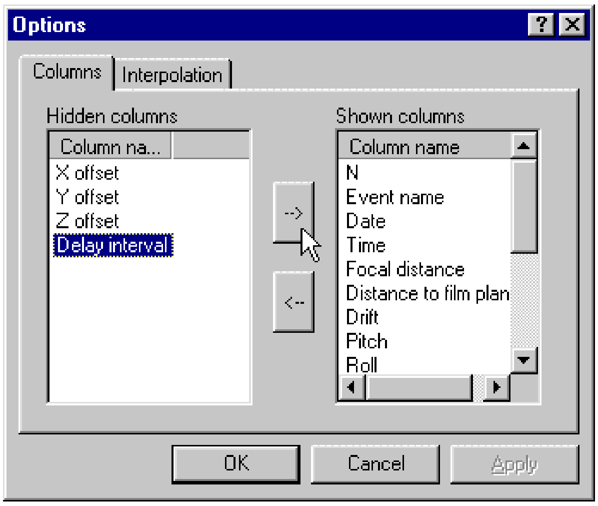


Figure 17. **Options** dialog box/**Columns** tab

The ***Interpolation*** tab allows the user to set the parameters governing the polynomial interpolation, specifically,

- Order of the interpolating polynomial
- Number of successive epochs (nodes) used to build the interpolating polynomial

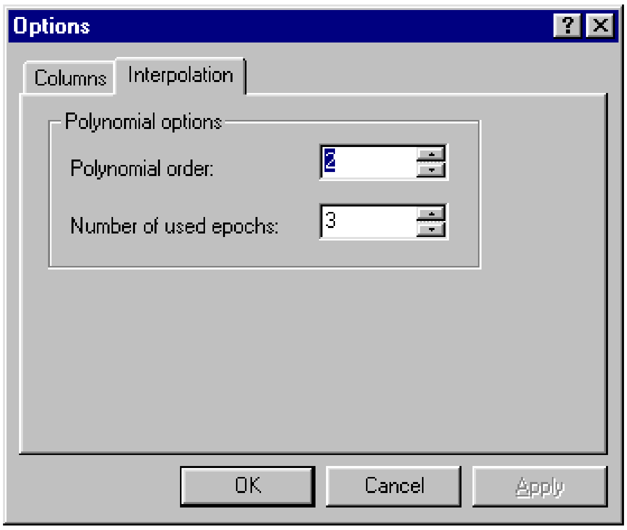


Figure 18. **Options** dialog box/ **Interpolation** tab

Ensure that the *Number of Used Nodes (Epochs)* is ***greater*** than the *Polynomial Order* (in fact, the program checks these two settings for consistency so that you cannot enter arbitrary integers here).

Recall that you can build a unique N-order interpolating polynomial passing through the given N+1 points. On the other hand, if the *Number of Used Nodes (Epochs)* parameter is greater than the *Polynonial Order* by more than one, the resulting interpolating polynomial will be a smoothing curve meeting the least-squares criterion.

If you right-click anywhere in the ***Event Editor*** window, a pop-up menu will appear:

Figure 19. ***Event Editor*** menu

You use the menu's commands to create new events or edit existing ones.

3.9. New event

A dialog box will appear prompting the user to specify the new event's properties (see section 3.15 Properties.)

3.10. Delete event

All the events that are selected (highlighted) in the list will be deleted. The user will be prompted to confirm delete. This command will be inaccessible (grayed out) if no events are selected.

3.11. Enable/Disable event

Disabled events will not be used when computing coordinates. The *Enable event* command will be inaccessible (grayed out) if no events are selected or if all selected events are already enabled. The *Disable event* command will be inaccessible (grayed out) if no events are selected or if all selected events are already disabled.

3.12. Copy

This command is used to copy the active columns of an event to the clipboard as tab-separated text. This command will be inaccessible (grayed out) if no events are selected.

3.13. Select all

Selects (highlights) all events in the list.

3.14. Create Point

New *Points* will be created in the project's current *Network* for each selected event. These points will have the coordinates of the corresponding events. To view the created points, select the ***Point List*** command from the *Network*'s pop-up menu. Also, the user can view the aircraft's trajectory together with the created Points. To do this, open the ***Network View*** window for the *Network*, or press (**show the whole Network**) button in the ***Network View*** window for the appropriate *Solution*.

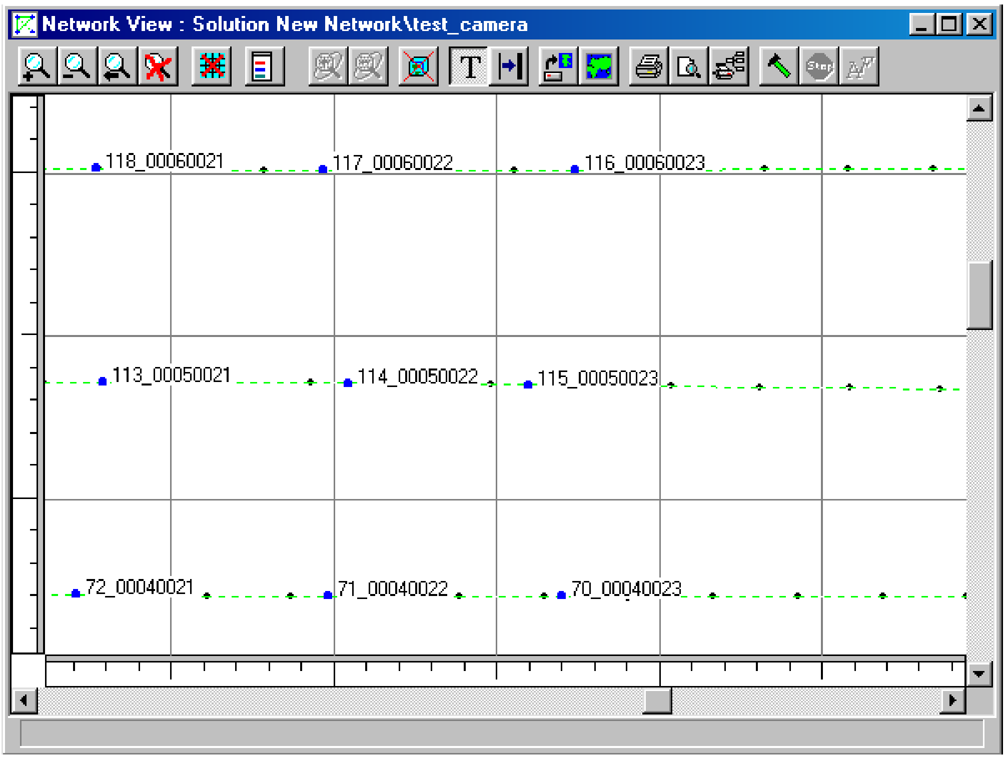


Figure 20. ***Network View*** for the trajectory and the *events-associated* points

This command will be inaccessible (grayed out) if no events are selected or if none of the selected events have known coordinates.

3.15. Properties

This command will allow you to change properties of selected events. The dialog box is comprised of four tabs.

3.15.1. *Event* tab

The user can edit the name, date and time of an event.

Note: Event time is displayed/entered in hours, minutes, seconds and *nanoseconds.*

This tab is not displayed if the ***Properties*** command has been applied to more than one event.

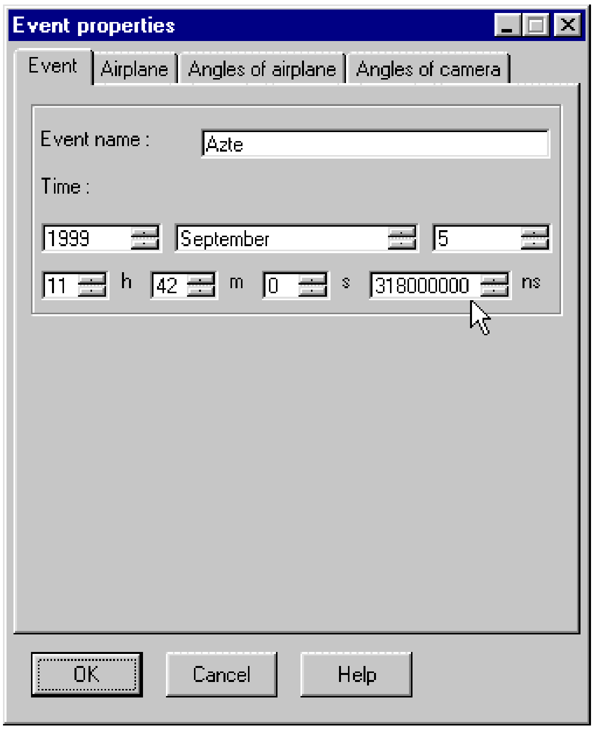


Figure 21. ***Properties*** dialog box /***Event*** tab

3.15.2. *Airplane* tab

The user can change the airplane's parameters for the selected events. These parameters are described in section 3.3 of this Manual.

3.15.3. *Angles of airplane* tab

The user can input the aircraft's orientation angles for the selected events. The coordinates of the events will be recalculated using these parameters as soon as you close the dialog box with the OK button. You cannot specify the airplane's angles (please note the N/A flag) if the *With Gyro* mode is selected.

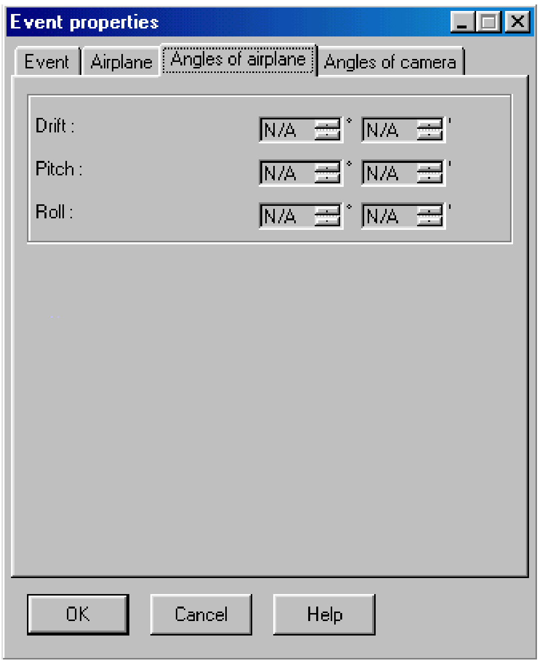


Figure 22. ***Properties*** dialog box / ***Angles of airplane*** tab

3.15.4. *Angles of camera* tab

The user can input the camera's orientation angles for the selected events.

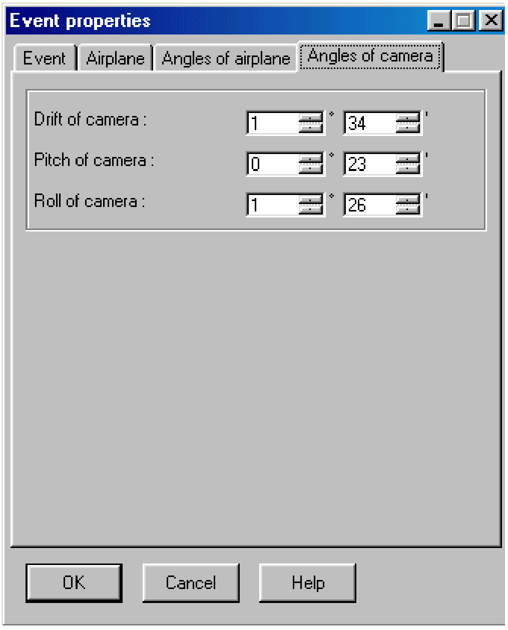


Figure 23. ***Properties*** dialog box / ***Angles of camera*** tab

If the camera has been mounted on a gyro mount, then only the camera's orientation angles are used in postprocessing when calculating event coordinates.

If the camera has been use in the 'without gyro' mode, then both the camera's and the aircraft's orientation angles are necessary for computation.

Pinnacle™
Reference Documentation Suite

Network adjustment

User's Manual

This document reflects
the April 4, 2001 version
of Pinnacle 1.0

Last revised July 12, 2001

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Table of Contents

1. *Introduction to Pinnacle network adjustment*

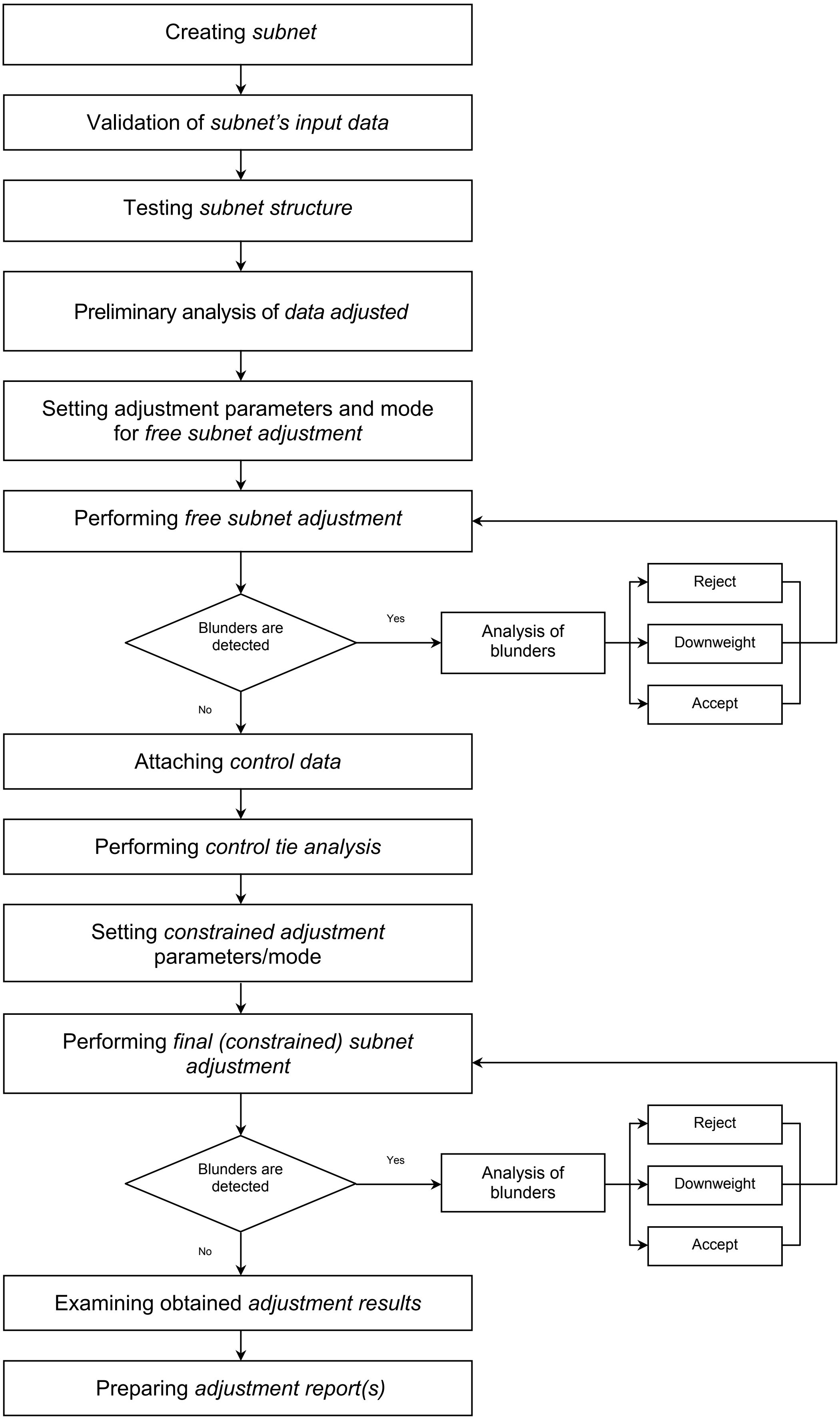
The process of adjusting a network[1] (or some part of a network) can be divided into the following three stages:

- **Preliminary analysis of the data adjusted (**a.k.a. **pre-adjustment).** This stage serves two main purposes. First, it allows the user to check the consistency of the given network as a whole. Second, it allows the preliminary detection of possible blunders in the vector data.
- **Free or Minimally constrained adjustment.** This adjustment is performed to evaluate the intrinsic accuracy of the GNSS network. One of the network points can be held *fixed* or, alternatively, an *inner constraint* may be used.
- **Adjustment constrained by local control (**or **final adjustment).** At this adjustment stage the GNSS network is constrained by more than one local control point. After the adjustment is complete, the user will have the coordinates of the network's points in the specified local datum.

A general flowchart of the adjustment process is shown in Flowchart 1.

[1]) In PINNACLE 1.0 the term 'network' designates a ***vector network*** based on GNSS measurements. For brevity we will also refer to such networks as "GNSS data networks" or simply "GNSS networks".

Network Adjustment Flowchart



Flowchart 1

The user will set necessary network adjustment parameters through the '***Properties for Subnet…***' and '***Network View Options***' dialog windows.

To open the '***Properties for Subnet…'*** window, the user must right-click on the subnet's node

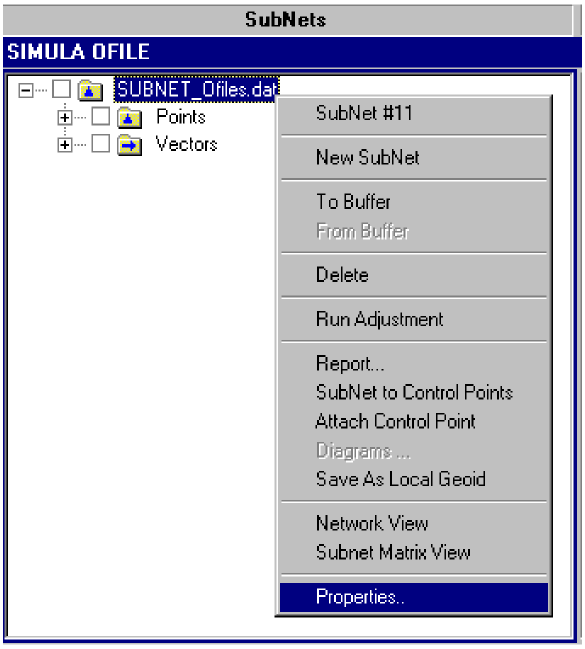


Figure 1-1

and then select the '***Properties..***' option from the context menu:

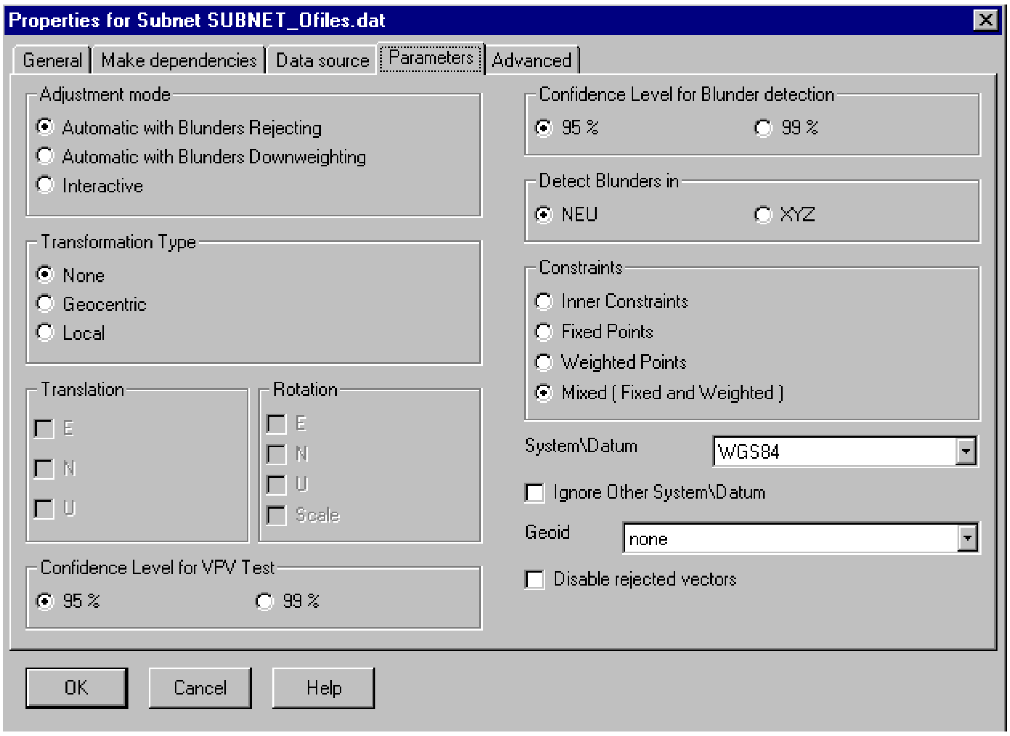


Figure 1-2

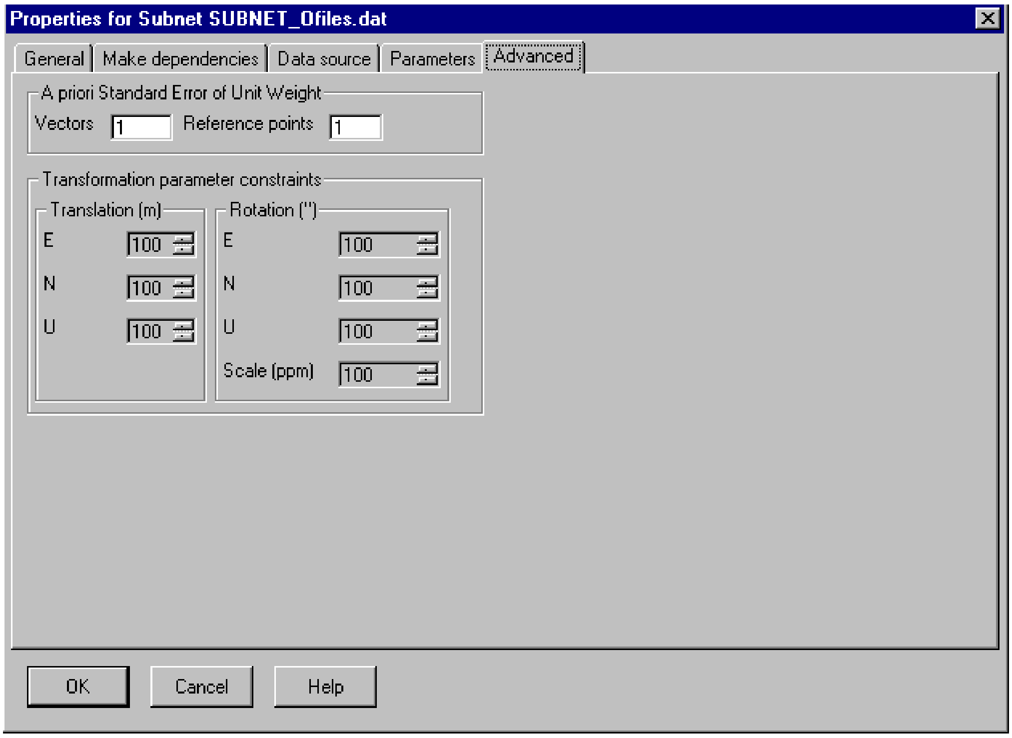


Figure 1-3

Note that the settings entered in the 'Parameters' and 'Advanced' tabs are normally referred to as *adjustment parameters* since they specify what adjustment mode will be used to adjust the given subnet and how specifically the adjustment will be carried out.

For the '***Network View Options***' dialog window, it serves the following two purposes. First, this window enables the user to specify the parameters governing the pre-adjustment tests. Second, it is used to enter the settings controlling the way in which graphical, text and other data will be displayed in the *Network View* window while running the pre-adjustment tests.

To invoke the '***Network View Options***' dialog window, the user must first open the '***Network View***' window by selecting the corresponding option from the context menu (see Figure 1-4),

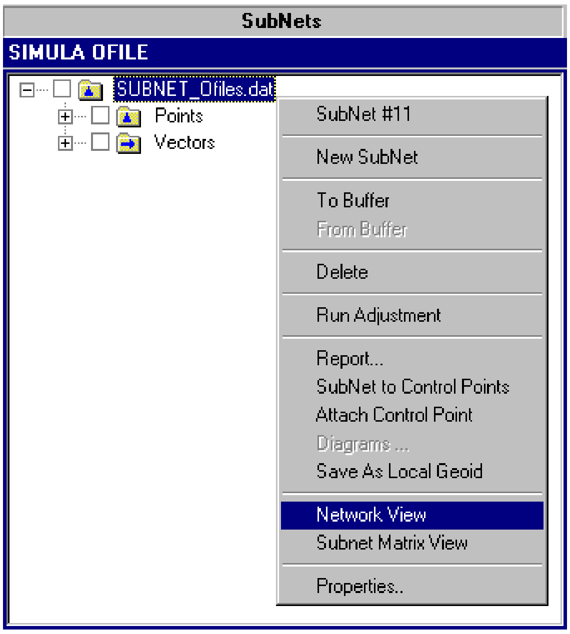


Figure 1-4

then right-click somewhere in the empty area of this window to open another menu,

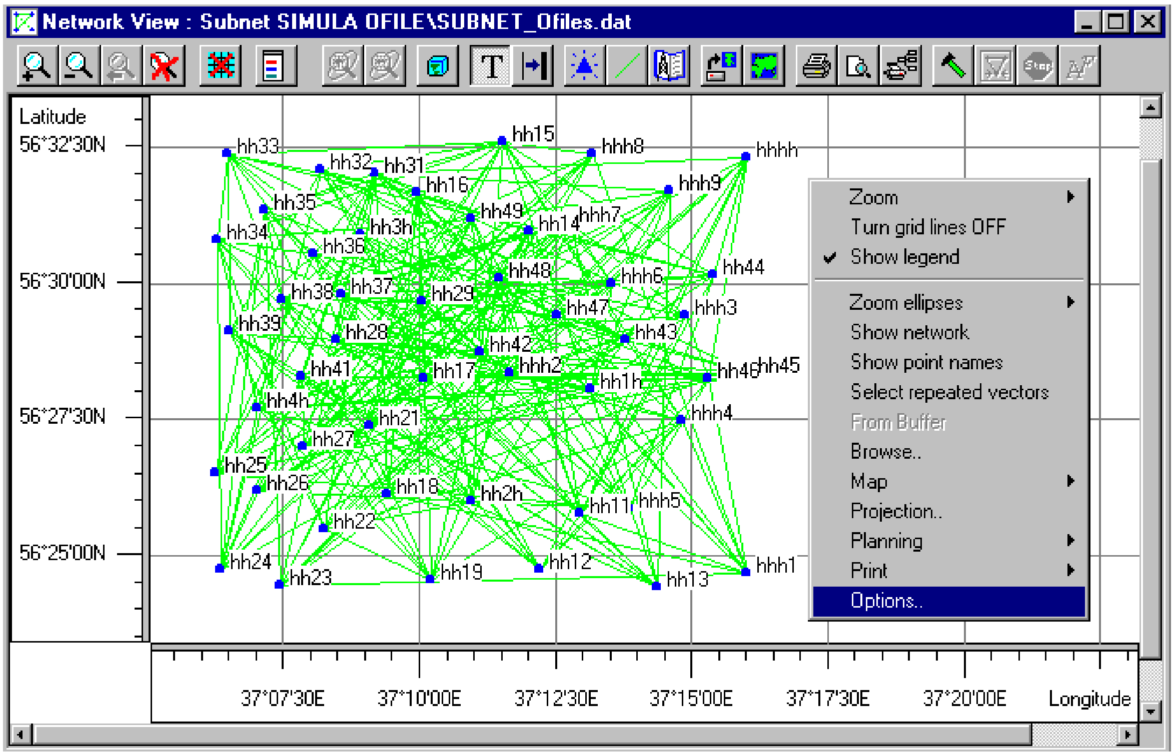


Figure 1-5

and finally select '***Options…***' from this context menu as shown in Figure 1-5:

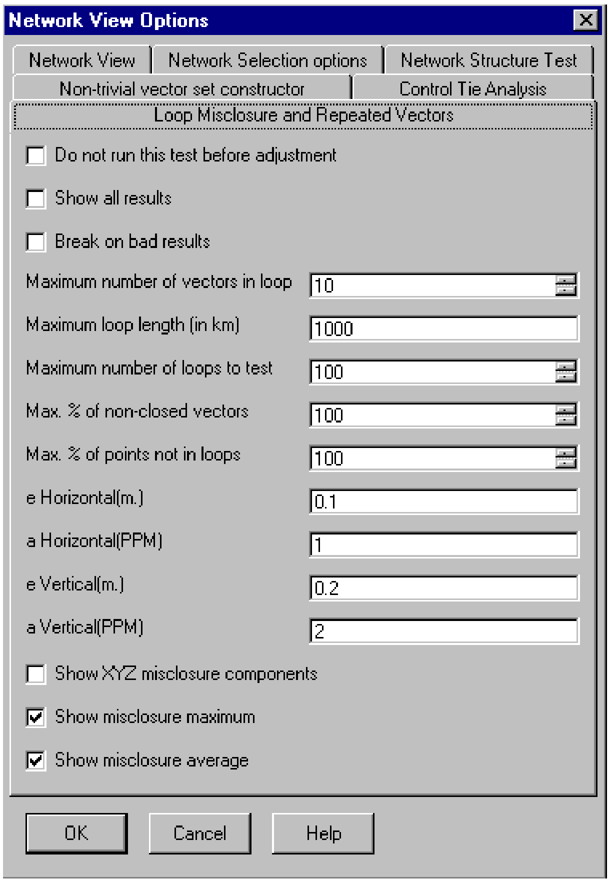


Figure 1-6

As seen from Figure 1-6, the '***Network View Options***' dialog window comprises six tabs.

In this section we will focus only on the ‘Network View’ and ‘Network Selection Options’ tabs (the other four tabs, which do with the pre-adjustment tests, will be described in detail in 2).

1.1. ‘Network View’ settings

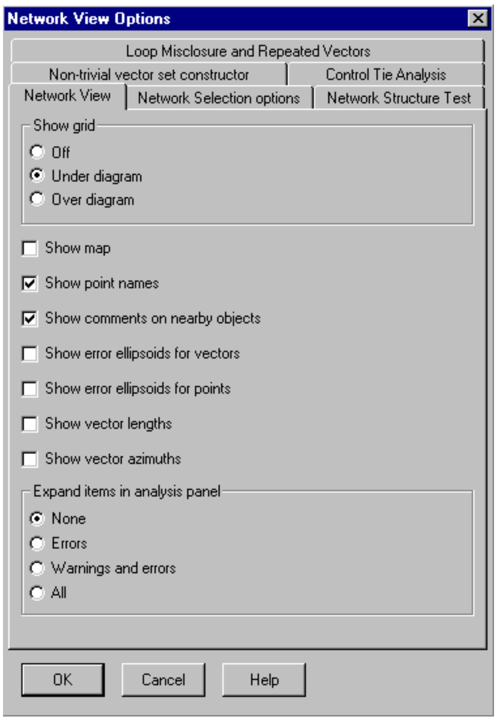
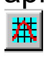
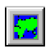


Figure 1-7

- The ***Show grid*** radio button group allows the user to change the grid display mode: hide the coordinate grid, show the grid lines under or over the network graph. The same results the user can get by pressing the toolbar's *Grid lines…* button  in the *Network View* window.
- The ***Show map*** checkbox enables the use of an appropriate map as a background when displaying the subnet in the *Network View* window.

  Such maps are stored in and loaded from the corresponding *map files*. Pinnacle 1.0 is capable of using *vector maps* only. Map files may have the following formats *.***dat*** (MapGen), *.***dxf*** (AutoCAD) , *.***map*** and *.***jff*** (TPS).

  Note that the Pinnacle 1.0 installation includes the map file ***coastline.map*** showing the world coastline.

  To load a map, press the toolbar's *Load Map* button  in the *Network View* window and then choose the desired map file from the file list. After the map has been loaded, it can be turned on and off with the toolbar's *Map on/off* button  in the *Network View* window or with the *Show Map* checkbox in the *Network View* tab. To load a map and set the desired display mode for it, the user will open the pop-up context menu by right-clicking somewhere in the empty area of the ‘Network View’ graph (see Figure 1-8).

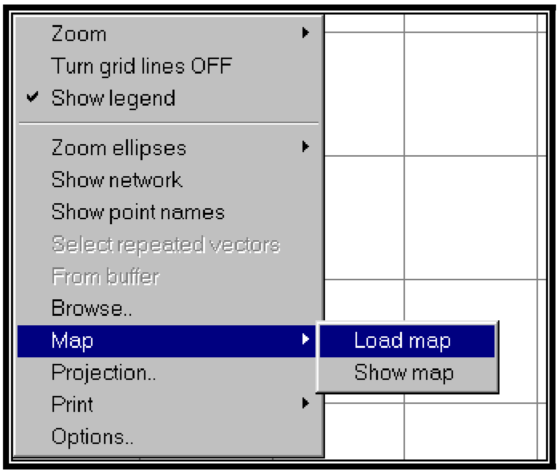


Figure 1-8

When importing a map file to Pinnacle 1.0, it will be converted into the **.jff* format (regardless of the map file's original format). Pinnacle 1.0 will prompt the user to save the imported map file as an **.jff* file.

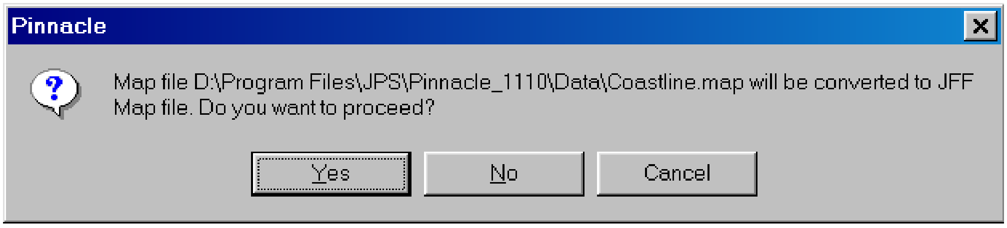


Figure 1-9

Note that the TPS proprietary map file file format, *.jff, not only allows rapid and correct import of a map's data to Pinnacle 1.0 but also provides the seamless transformation and efficient storage of the map objects' coordinates in different coordinate systems.

- The ***Show point names*** and ***Show comments on nearby objects*** checkboxes are used to show or hide the point names and comments on the nearby objects (see Figure 1-10).

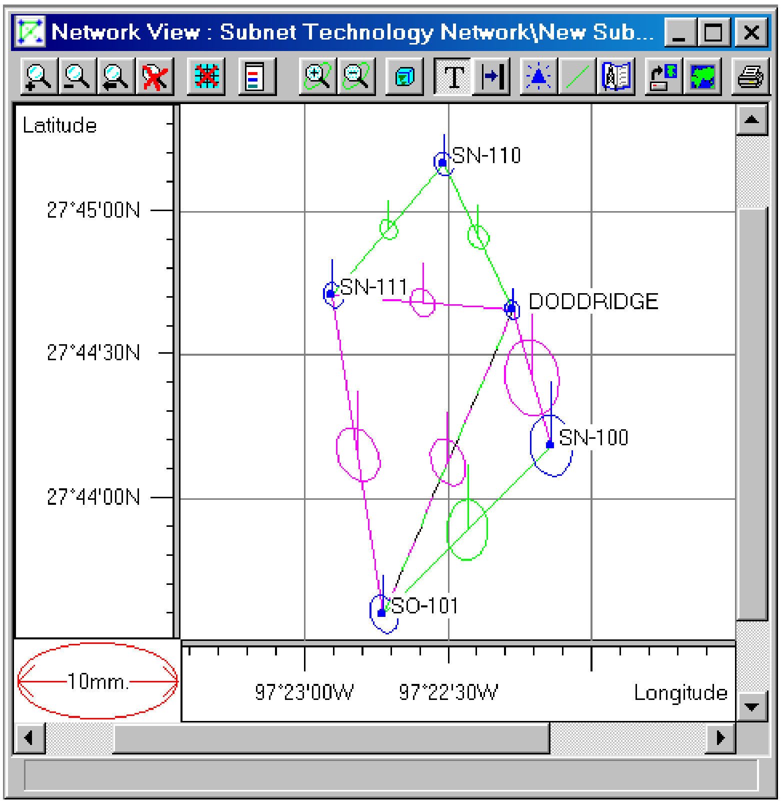


Figure 1-10

- The ***Show error ellipsoids for vectors (points)*** checkboxes are used to turn on and off the 3-D *graphical accuracy indicators* for the processed points and vectors. Recall that a point's *error ellipsoid* is uniquely defined by the matrix inverse to the variance-covariance matrix estimated for this point[2]. For reasons of convenience and simplicity, *vertical errors* and horizontal *error ellipses* are used in the 'Network View' window to describe the accuracies of the subnet's vectors and points.

  Recall that the probability of the true value of a 3-d parameter such as a subnet's point or vector falling inside the corresponding error ellipsoid is about 0.199.

  After the error ellipsoids are estimated in the XYZ frame, they can be easily re-calculated in NEU of course. Next, the error ellipsoid will be projected onto the local horizon plane, thus producing the error ellipses indicating the horizontal accuracy of the network's vectors and points. In addition, the error ellipsoids are projected on the local normal, which shows the vertical accuracy.

  A vector's vertical and plane errors will be shown in the same color in which the vector itself is marked. Note that vectors in the '*Network View'* window may be marked in ***green***, ***magenta***, ***red***, *gray* or ***black*** color depending on their status and the results obtained at the pre-adjustment and adjustment stages. Specifically,

  1) ***Green*** color is used to mark *good* vectors. Vectors are called *good* if

     - they are enabled processed vectors
     - they have passed all of the pre-adjustment and adjustment tests.

  2) Unprocessed enabled vectors will be highlighted in ***black*** color (e.g., hhh9 → hhhh, hh4 → RIGHT in Figure 1-11)

[2]) Same is true for a vector's error ellipsoid of course.

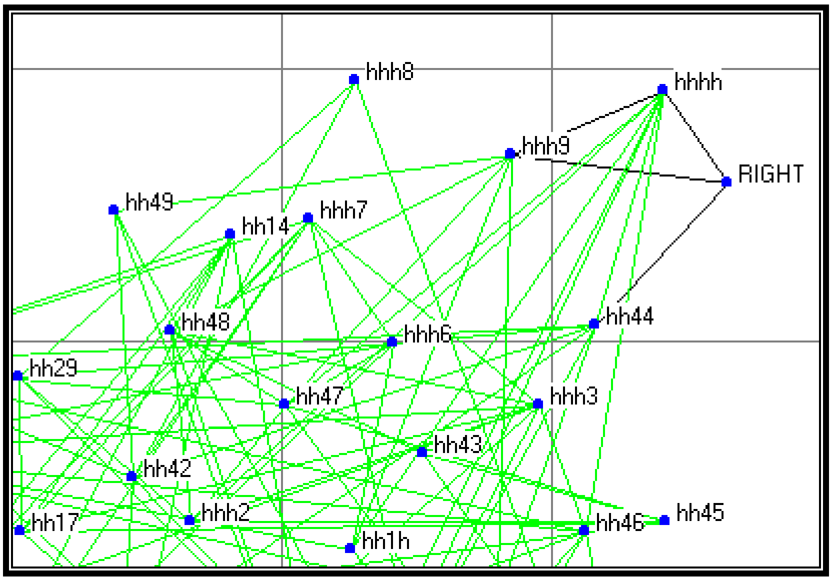


Figure 1-11

3) Unprocessed disabled vectors will be highlighted in ***gray*** color (e.g., hhhh → RIGHT, hhh9 → RIGHT in Figure 1-12)

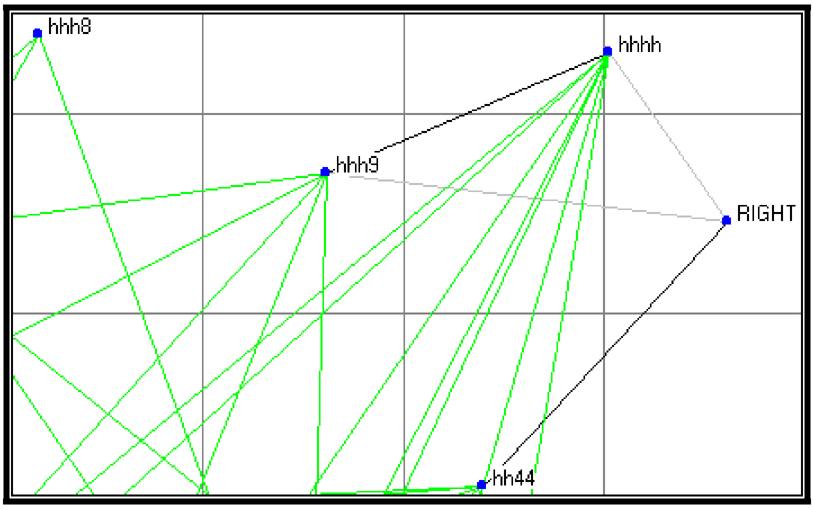


Figure 1-12

4) Vectors identified as outliers ('blunders') when adjusting a subnet in the '*Automatic with Blunder Rejecting*' or '*Interactive*' mode, will be marked in ***red*** color (e.g., hh14→ hh17 in Figure 1-13):

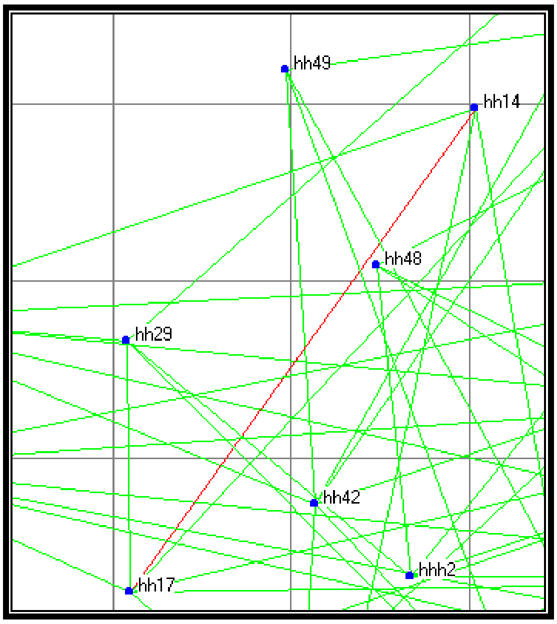


Figure 1-13

5) Vectors identified as outliers when adjusting a subnet in the '*Automatic with Blunder Downweighting*' or '*Interactive*' mode, will be marked in ***magenta*** color (e.g., hh14→ hh17 in Figure 1-14).

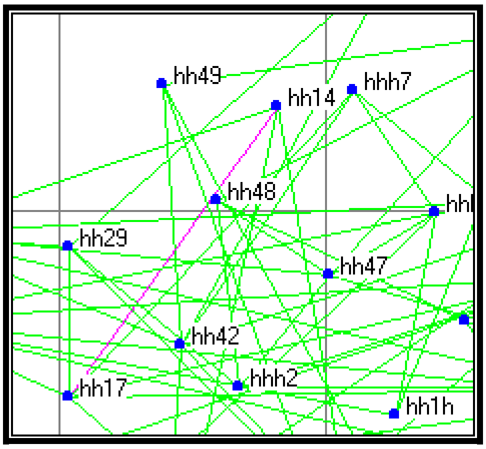


Figure 1-14

Enabled points and their vertical and horizontal errors will be shown in blue color. Disabled points and their vertical and horizontal errors will be marked in gray color (see points *hhh8* and *hhh9* in Figure 1-15)

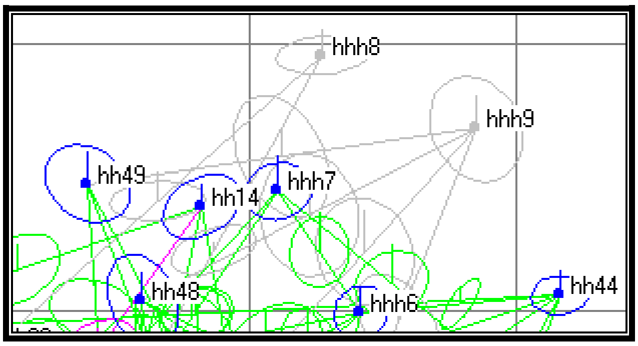


Figure 1-15

The actual sizes of the error ellipses can be easily recognized by comparing them to the red reference ellipse shown in the bottom-left-hand corner of the *Network View* window (see Figure 1-10).

- The ***Show vector lengths*** and ***Show vector azimuths*** checkboxes are used to turn on and off information on the lengths and azimuths of the vectors shown in the *Network View* window.
- The ***Expand items in analysis panel*** radio button group allows the user to expand and collapse the *analysis panel* tree. If the ***All*** checkbox is checked, the analysis panel tree will be completely expanded. If the ***Warning and errors*** box is selected, the warning and error messages will be completely expanded. If the ***Error*** box is checked, only the error messages will be expanded. Selecting the ***None*** checkbox keeps the analysis panel's tree collapsed.

1.2. Network Selection Options

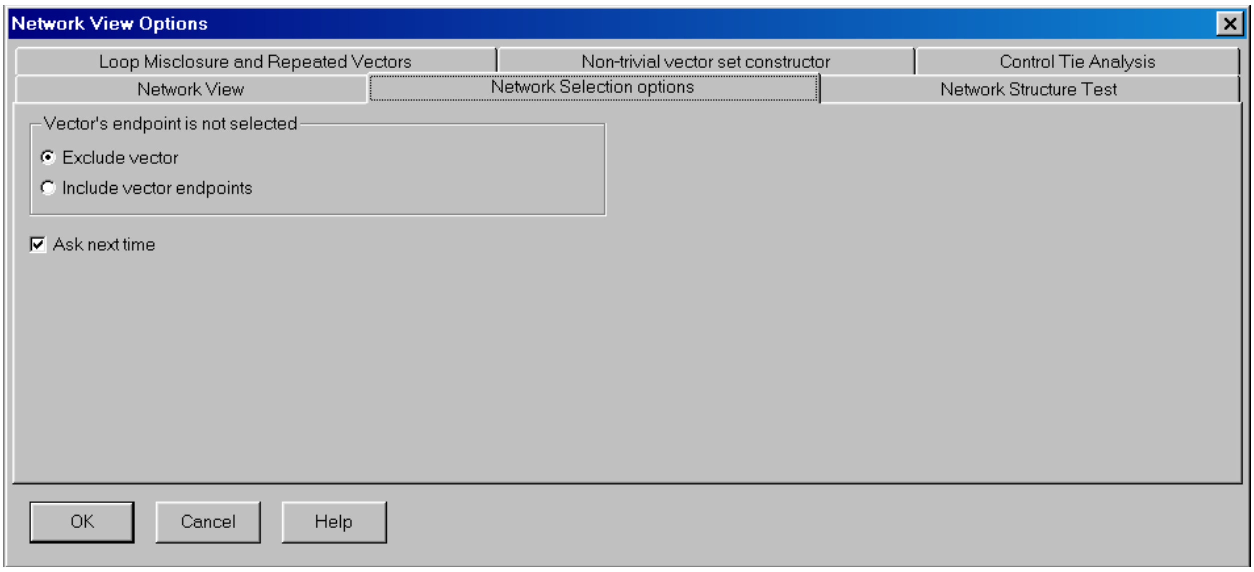


Figure 1-16

- The purpose of the ***Vector's endpoint is not selected*** radio button group is as follows:

  Since vectors and points are selected independently, a selected vector may have one of its endpoints unselected. To resolve this condition, the user must either exclude each of such problem vectors, thus removing them from testing, or, alternatively, treat such vectors as if their endpoints are selected, thus including the vectors in testing.
- The ***Ask next time*** checkbox allows the program to prompt the user in such cases.

2. *Pre-adjustment tests*

The user can create[3] a subnet by drag-and-dropping one or more solutions from the *Solutions* panel to the *Subnets* panel. Before adjustment is carried out, it is necessary to verify if the subnet has 'normal' structure and its raw data are free of blunders. To accomplish this task, the user will run the ***pre-adjustment tests***.

It is necessary to check the subnet data for integrity each time new information has been input into the subnet. It allows for the earliest detection and rejection of possible measurement blunders existing in the raw data. Also, it enables the user to discover the data whose measures of quality do not meet the specified requirements.

Right-click on the icon of the given subnet in the *Subnets* panel and select *Network View* from the pop-up menu. Alternatively, the user can invoke the *Network View* window by pressing the button after the desired subnet is selected.

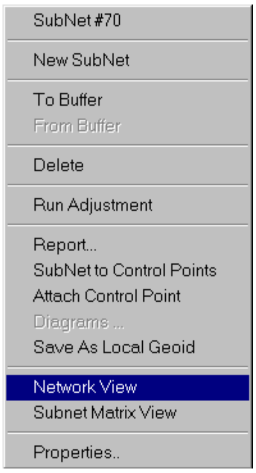


Figure 2-1

Press the button on the *Network View* toolbar to activate the *Test Subnet* menu.

Figure 2-2

Alternatively, the *Test Subnet* menu can be activated by right-clicking somewhere in the right-hand panel[4] of the *Network View* window.

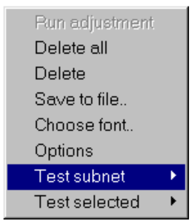


Figure 2-3

---

[3]) Assuming the user has already finished with all preceding steps (opening a project, creating a network, importing raw data into sessions and solutions, processing vectors)

[4]) This panel is also referred to as the *analysis panel* of the *Network View* window.

In Pinnacle 1.0 the following pre-adjustment tests are available:

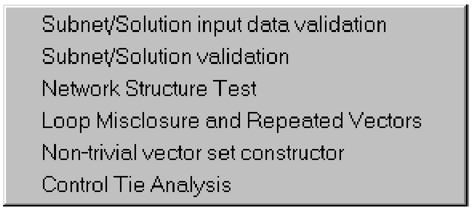


Figure 2-4

Depending on the test results obtained, the messages in the right-hand panel (a.k.a. *analysis panel*) of the *Network View* window will start with the following marks:

- test is passed successfully;

- error is found (such an error *may or may not* prevent from performing adjustment);

- warning (such a warning <u>*will not*</u> prevent the program from further operation).

The tests are intended to serve the following purposes.

2.1. Subnet/Solution Input Data Validation

In fact this test applies to both solutions and subnets. Note that the test will run *differently* for solutions and subnets.

When this test is run for a solution, Pinnacle 1.0 will check whether the solution's vectors have sufficient occupations.

When this test is run for a subnet, Pinnacle 1.0 will check whether the subnet's vectors are sufficient to run adjustment.
If an *unprocessed* (yet enabled) vector is found in the subnet, an <u>***error***</u> will be displayed for this vector in the analisys panel (see Figure 2-5).

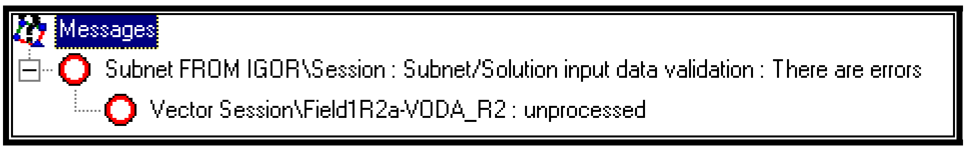


Figure 2-5

If an 'obsolete'[5] processed vector is detected, a <u>***warning***</u> will be reported for this vector (see Figure 2-6). It should be noted here that this test <u>will not</u> report the 'obsolete' warning if the user has disabled some of the subnet's points and vectors.

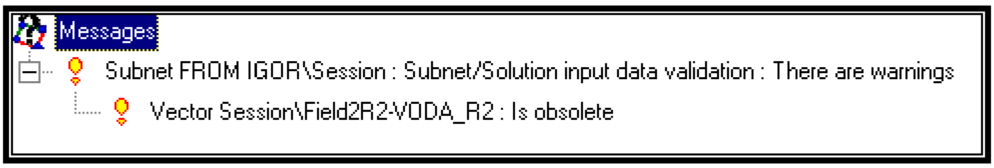


Figure 2-6

Finally, if a processed vector with a very large rms position error (>1m+10 ppm) is found, such a vector too will be marked with in the analisys panel tree.

---

[5]) A processed vector is called *obsolete*, if its *engine properties* have been updated since processing this vector last.

2.2. Subnet/Solution Validation

If this test is run for a subnet that has not been adjusted, an ***error*** will be reported (see Figure 2-7).

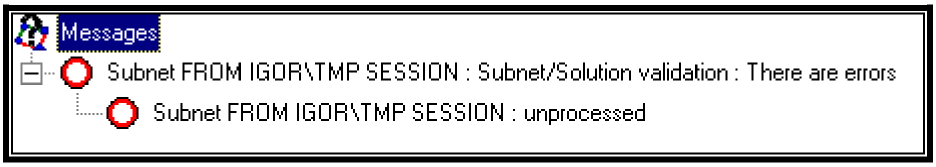


Figure 2-7

If this test is run after some of the adjustment parameters have been updated, a ***warning*** will be displayed indicating that the existing adjustment results have become '*obsolete*' (see Figure 2-8) .

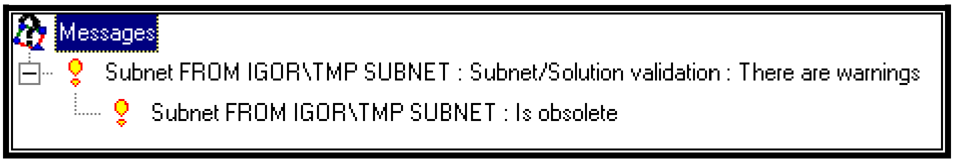


Figure 2-8

Note that this test will also generate a warning if some of the subnet's points or vectors have been disabled after running the adjustment last.

2.3. 'Network structure' test

This test allows for verification of the geometrical integrity of the subnet, i.e., it will help identify the subnet's components that are isolated from each other ("***isolated components***"), or those spanned by a single vector ("***bridge***") or point ("***junction point***") as well as the "***single-ended***" vectors. Network statistics will be calculated, which allows the user to compare the obtained results with the specified requirements (e.g., NGS specifications).

The easiest way to define the above mentioned 'irregular' component types is with an appropriate example network such as the one shown in Figure 2-9

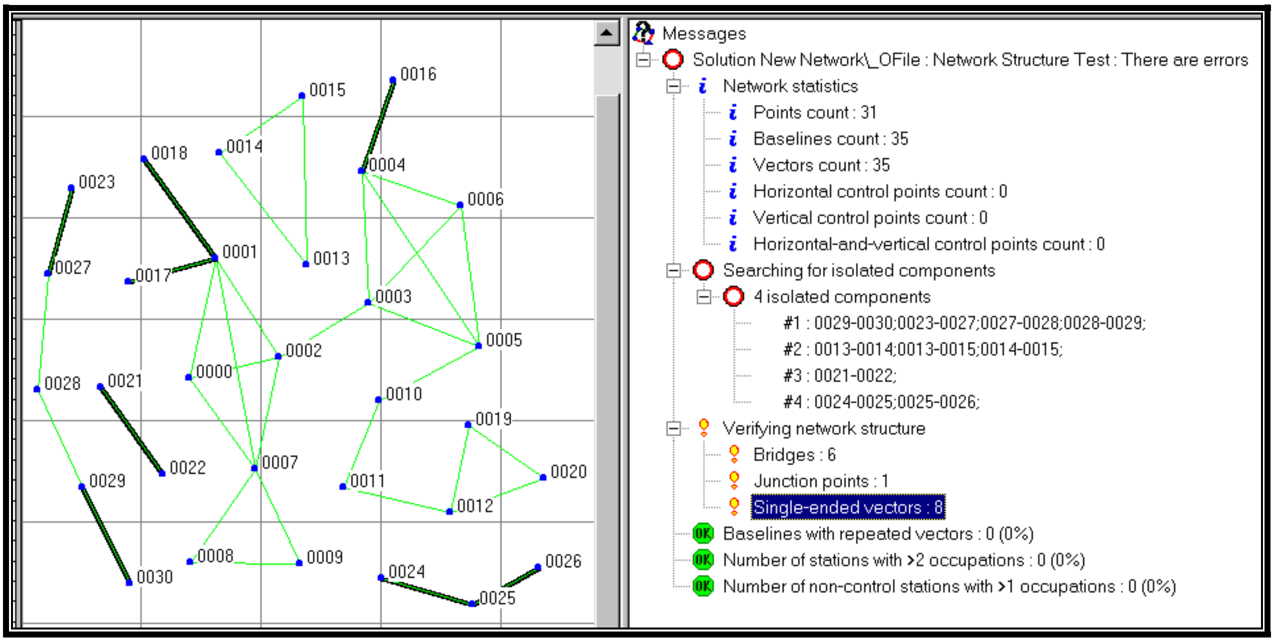


Figure 2-9

If one of a vector's endpoints are not connected to another vector, then the vector is called *single-ended*. In the example network shown in **Figure 2-9** there are seven *single-ended* vectors (they are highlighted in a dark color). Specifically, these are: 0001-0017, 0001-0018, 0004-0016, 0021-0022, 0023-0027, 0024-0025, 0025-0026 and 0029-0030.

A vector connecting two network components is called a *bridge* if there are no other points or vectors connecting these two components. In the example subnet shown in **Figure 2-10** there are six bridges, specifically: 0002-0003, 0005-0010, 0010-0011, 0011-0012, 0027-0028 and 0028-0029.

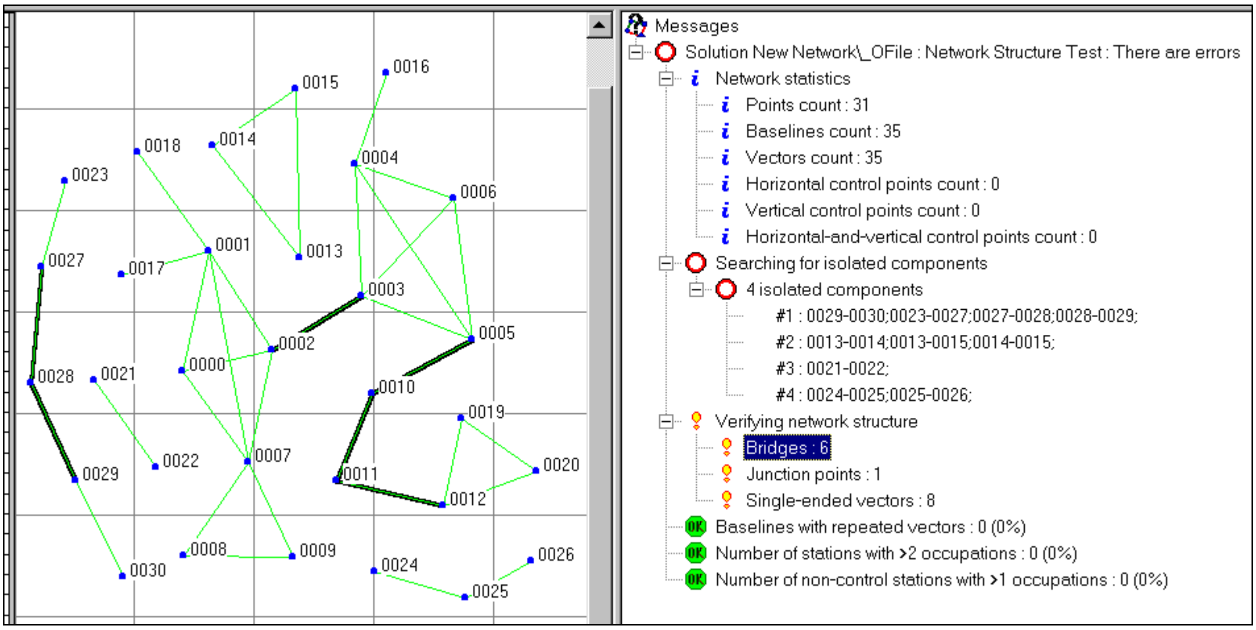


Figure 2-10

A point 'connecting' two network components, either of which having one or more vector loops in it, will be called a *junction point,* if there are no other common points or vectors connecting these two components. In our example network there is one junction point, 0007 (see **Figure 2-9** or **Figure 2-10**).

Note that bridges, junction points and single-ended vectors will be reported as ***warnings*** (not errors), and the corresponding message in the analysis panel will be marked with . Note that 'irregular' components, if any are found in the subnet, will not prevent from performing free or constrained adjustments. Also note that although such components are 'useless' in terms of free adjustment they however may be critical when running final (constrained) adjustment.

A network's components are considered *isolated* if they do not have common vectors or junction points and if there are no bridges between them. In our example subnet, there are four isolated components (in addition to the main part of the subnet), specifically: the vector triangle (0013-0014, 0013-0015, 0014-0015), the separate vector 0021-0022, the pair of vectors (0024-0025, 0025-0026) and the vector chain consisting of the links 0023-0027, 0027-0028, 0028-0029, 0029-0030.

Note that *isolated components* will be reported as ***errors*** and the corresponding message in the analysis panel will be marked with . This means that each detected isolated component will be a show-stopper preventing from further subnet adjustment.

There are two ways to perform a free adjustment of a subnet that includes isolated components.

The first approach is that the user can divide the entire network into separate reqular subnets and then adjust these subnets one by one.

The other approach is to adjust each isolated component, treating it as part of the original network, after temporarily disabling all the points and vectors not belonging to this component. To disable a vector, right-click on it in the *Network View* graph and choose the *Disable in Subnet* option from the pop-up menu.

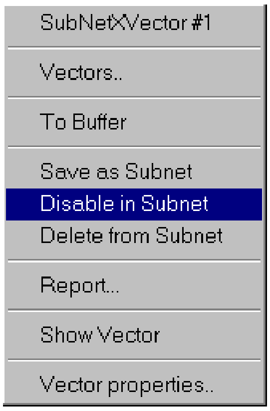


Figure 2-11

To set the parameters governing the test, the user must go to the 'Network Structure Test' tab of the 'Network View Options' window (see Figure 2-12).

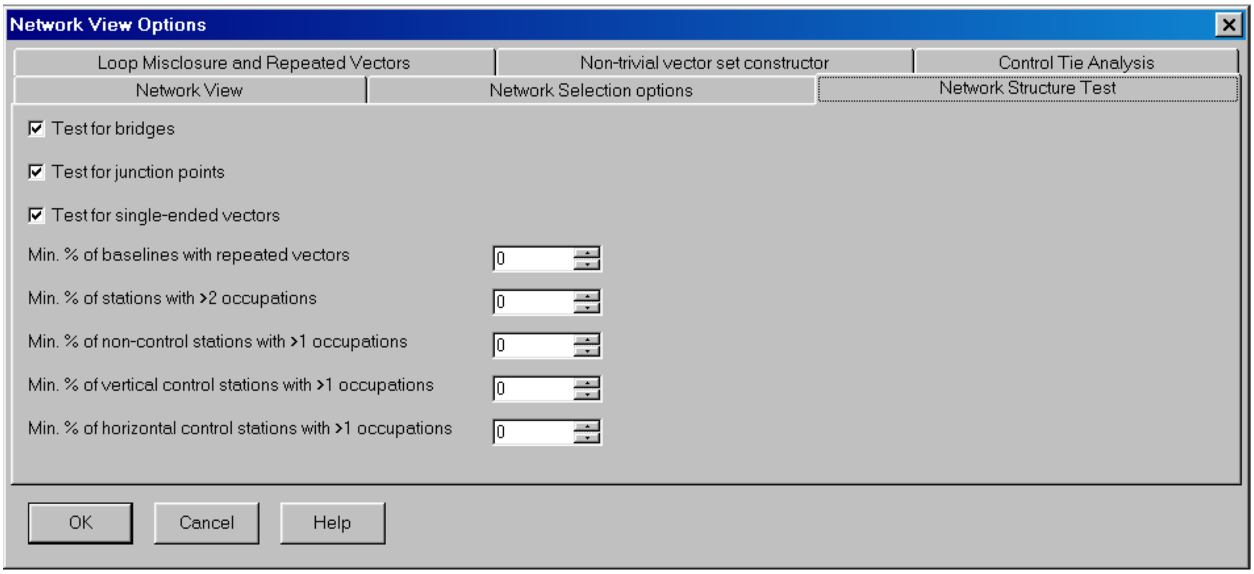


Figure 2-12

- If the ***Test for bridges***, ***Test for junction points, Test for single-ended vectors*** checkboxes are checked, Pinnacle 1.0 will search for bridges, junction points and single-ended vectors, respectively. If ***none*** of these checkboxes is checked then only the subnet's *isolated components* will be looked for.
- The ***Min % of …*** group of spinboxes enables the user to check whether the given subnet meets some "third-party" criteria/specifications (for example, NGS specifications).

  Note that if some of the test results do not meet the specified tolerances, the corresponding message in the analysis panel tree will be marked with ○.

2.4. ‘Loop Misclosure and Repeated vectors’ test

This test will serve two purposes. First, the test will generate all possible[6] vector loops and compute the XYZ- or NEU- misclosure errors corresponding to these loops. Second, this test will show the XYZ- or NEU-discrepancies between the multiple vector measurements (“repeated vectors”) relating to the same baseline. To display the misclosure errors for the vector loops or multiple vector baselines, click on the corresponding item (i.e., *loop* or *vector*) in the analysis panel of the *Network View* window. The selected item will be highlighted in a dark color in the *Network View* graph.

Misclosures are calculated only for *simplex* loops. A vector loop is called *simplex* if it cannot be divided into two smaller non-trivial loops based on the vectors available in the given subnet.

It is possible that some of the baselines in a loop have multiple (repeated) vector measurements. In this case all possible vector combinations will be tested for the loop.

If the corresponding options are selected, Pinnacle 1.0 will compute and show the maximum and average misclosure errors for each loop.

In addition, the total number of loops and the number of bad loops including the given vector will be reported. The test results for each vector will be displayed in the order of decreasing of the percentage of the bad loops relating to the given vector. This approach makes it much easier for the user to identify suspect vectors.

This test often helps to detect antenna height blunders and other problems with correct measuring antenna offsets.

The user may want to test only a specific part of the given subnet. To select the desired vectors/baselines on the network view, click on them while holding down the *Shift* or *Ctrl* key. The selected vector loops will be highlighted in a dark color. Then press the  button, choose the *Test selected* option and the *Loop Misclosure and Repeated vectors* test. Check the *Add vector ends* checkbox in the *Network Selection Options* tab. Finally, press *OK* to start the testing of the selected vector loops.

To set the parameters governing the test, the user must go to the ‘Loop Misclosure and Repeated Vectors’ tab of the of the ‘Network View Options’ window (see Figure 2-13)

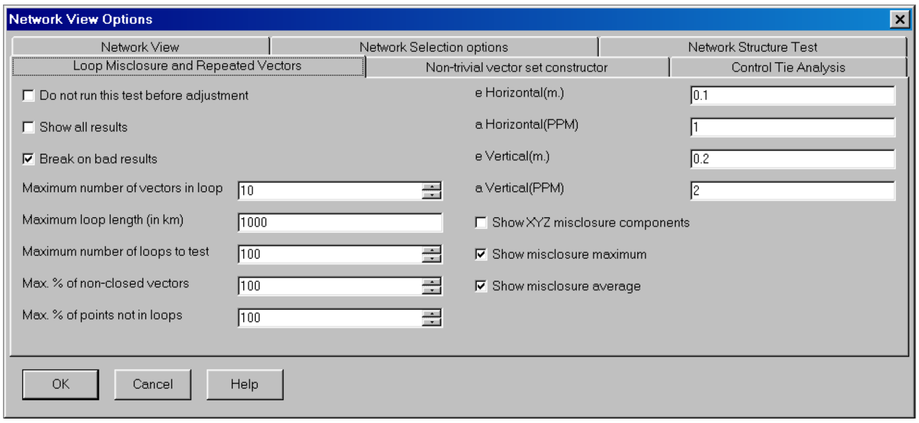


Figure 2-13

- The ***Do not run this test before adjustment*** checkbox is used to skip the *Loop Misclosure and Repeated vectors* test when the pre-adjustment tests and adjustment

[6]) in accordance with the settings specified in the *Loop Misclosure and Repeated vectors* tab

are performed 'at one run' by pressing the '*Run Adjustment*' option (or clicking the button in the '*Network View*' window).

- The ***Maximum Number of Loops to Test*** parameter indicates the limit on the number of loops tested. Such a limitation is <u>*especially*</u> important when processing big networks with very many simplex loops. In this case the computation time to build and analyse all of the existing simplex loops can be unacceptably large.

  When the actual number of loops available in the subnet exceeds the imposed limit, the *Testing loop misclosures* node in the analysis panel will be marked with . In this case the test is called 'truncated'. For a truncated test, the expanded *Testing loop misclosures* tree will contain the warning "*Maximum number of loops tested*" at the bottom (see Figure 2-14):

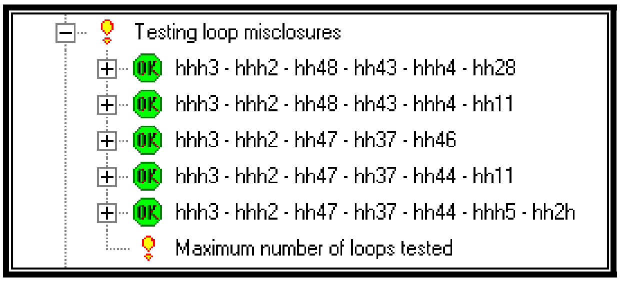


Figure 2-14

- If the ***Show All Results*** checkbox is checked, the program will test and display in the analysis panel the first ***N*** of the existing loops (whether good or bad), where

$$N = \min(N_{total}, \textit{Maximum Number of Loops to Test}),$$

N_{total} is the total number of the loops existing in the subnet.

Good loops will be marked with , bad ones with .

In the example shown in Figure 2-15 the parameter N_{total} >> *Maximum Number of Loops to Test = 10:*

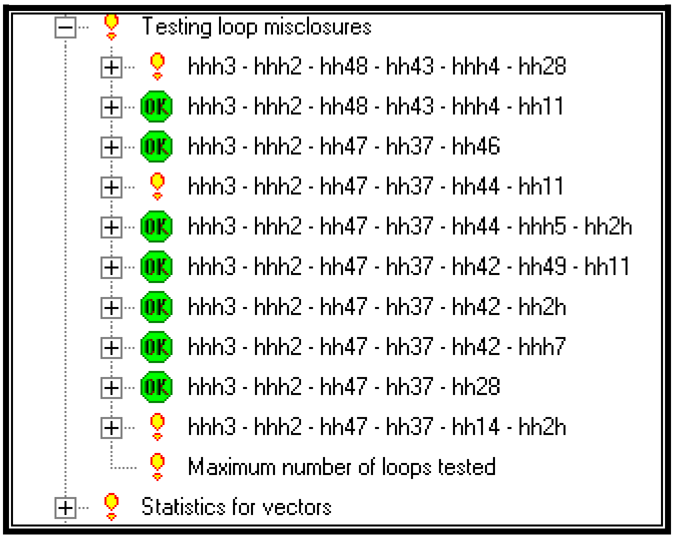


Figure 2-15

If the ***Show All Results*** checkbox is unchecked, Pinnacle 1.0 will report <u>only the bad</u> loops detected when analysing the first ***N*** loops (see Figure 2-16).

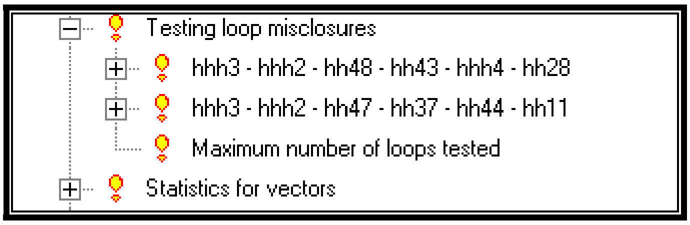


Figure 2-16

- The constant '**e**' (in meters) and the linear factor '**a**' (in ppm) will define the tolerances used when analysing misclosures in the *Vector Loops and Repeated vectors* test. The equation for tolerances **T** is as follows:

T(loop) = *SQRT*(Number of Vectors in Loop) ·e + a·Loop Length

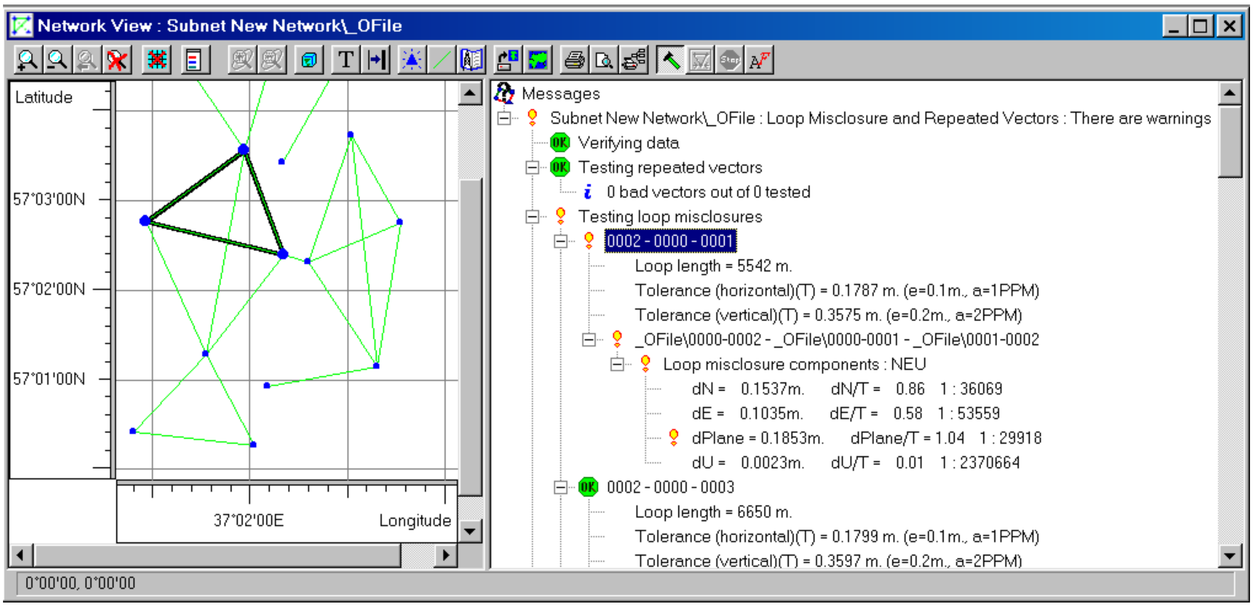


Figure 2-17

- The ***Break on bad results*** checkbox indicates what will occur if the *Loop Misclosure…* test is not passed. If this checkbox is checked and the test fails to meet the specified tolerances, the program will interrupt further adjustment. If this checkbox is unchecked, the program will continue the adjustment even if the test fails. Note that if the ***Break on bad results*** checkbox is selected, the warning icon will be replaced with the error icon in the 'Testing loop misclosures' tree (compare Figure 2-16 with Figure 2-18)

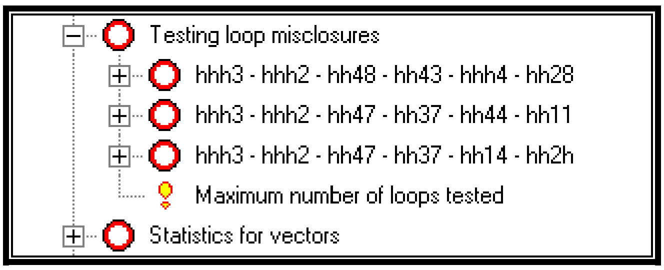


Figure 2-18

- The ***Maximum number of vectors in loop*** spinbox indicates the limit on the maximum number of vectors in loops. If the number of vectors in a loop exceeds the threshold value, this loop will be excluded from the test. Obviously there must be a minimum of three vectors in a loop.

- The ***Maximum loop length (in km)*** edit box indicates the limitation imposed on *loop length* (in kilometers). If the total length of the vectors in a loop exceeds the specified limit, the loop will be excluded from the test.
- The ***Max. % of non-closed vectors*** spinbox specifies the limit on the number of vectors that do not belong in any loop. For example, they can be separate vectors, single-ended vectors, bridges and vectors from to the so-called *vector chains*. If the actual percentage of untested vectors as compared to the total number of vectors exceeds this limit, the test will be considered unsuccessful.
- The ***Max. % of points not in loops*** spinbox specifies the limit on the number of points that do not belong in any loop. For example, they can be the endpoints of separate or single-ended vectors, or the endpoints of vectors from *vector chains*. If the actual percentage of the *non-loop* points exceeds this limit, the test will be considered unsuccessful.
- The ***Show XYZ Misclosure components*** checkbox is used to select the coordinate system(s) in which misclosure errors will be displayed. If this checkbox is unchecked, the program will display the loop misclosure errors only in ENU. Otherwise the misclosure errors will be shown both in ENU and XYZ.

The ***Show Misclosure Maximum*** and ***Show Misclosure Average*** checkboxes allow the user to view the maximum and average values of the misclosure errors computed using all possible vector combinations for each loop (recall that some of a loop's baselines may have multiple vector measurements).

2.5. Non-Trivial Vector Set Constructor

To give the reader an idea of what trivial and non-trivial vectors mean, let us begin with a simple example illustrating the problem.

Suppose we have three receivers simultaneously collecting GNSS data at three different sites somewhere in an open area. Assuming that the data collection start and end times, the acquired satellites and all the other conditions are <u>exactly the same</u> for the three receivers. Since all the three vector estimates (baselines) will be derived from the same three raw data files, we can expect that the errors εx_1, εy_1, εz_1 of the first baseline will be <u>highly correlated</u> with the errors εx_2, εy_2, εz_2 and εx_3, εy_3, εz_3 of the other two baselines. Therefore, only two of the three vector estimates are expected to be *informative* and worth using in further adjustment. The third vector estimate, which *closes* the loop, will provide no additional information, and therefore it should be excluded from further post-processing altogether. This explains why such a loop is called '*trivial'*. In turn, the vector that is part of a trivial loop and that is selected to be removed from adjustment will be referred to as *trivial*.

The problem is that the Pinnacle adjustment module <u>does not allow</u> the user to enter the true weight matrix (if known) for vectors generating trivial loops. This feature is unavailable because Pinnacle does not support *multiple station vector processing*. In other words, vectors imported into a subnet and adjusted by the Pinnacle adjustment module are assumed to be mutually uncorrelated (independent).

It is known that adjusting a subnet with mutually dependent vector measurements as if these measurements are independent may result in distorted (over-optimistic) final accuracies of the adjusted points. The simplest way to avoid getting over-optimistic variances for the adjusted points is exclude as many trivial vectors as possible (without badly affecting the subnet's integrity of course).

Another way to handle trivial vectors is as follows.

The user needn'd remove such vectors from the given subnet. Instead, the user will use all available (both trivial and non-trivial) vectors when performing the free adjustment of the subnet. If the percentage of the trivial vectors in the subnet is high enough, the variances of the coordinates of the 'adjusted points' will be noticeably 'over-optimistic' (i.e., smaller than they should be). To compensate for this effect, the user must scale the final variances of the points' coordinates by the factor C=T/N (>1), where

T – total number of vectors in the subnet

N – number of the non-trivial vectors as reported by the test

Note however that PINNACLE 1.0 utilizes a simplified criterion of *trivial loop*. A loop is called *trivial* if for each pair of adjacent vectors in the loop the occupation times for the corresponding three endpoints fully or partially *overlap*. For example, Figure 2-19 shows that the occupation time intervals for points 1, 2 and 3 overlap (the common interval is highlighted in red)

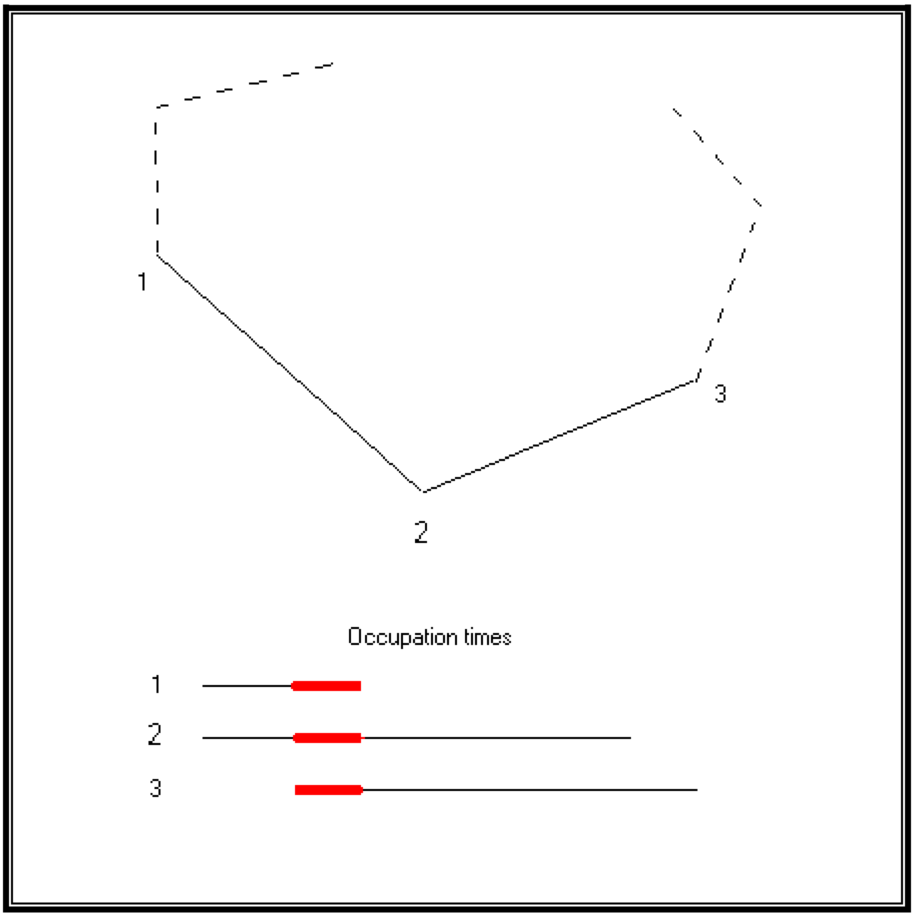


Figure 2-19

Lastly, suppose a loop is recognized as trivial. A question arises: which of the loop's vectors should be excluded from further adjustment?

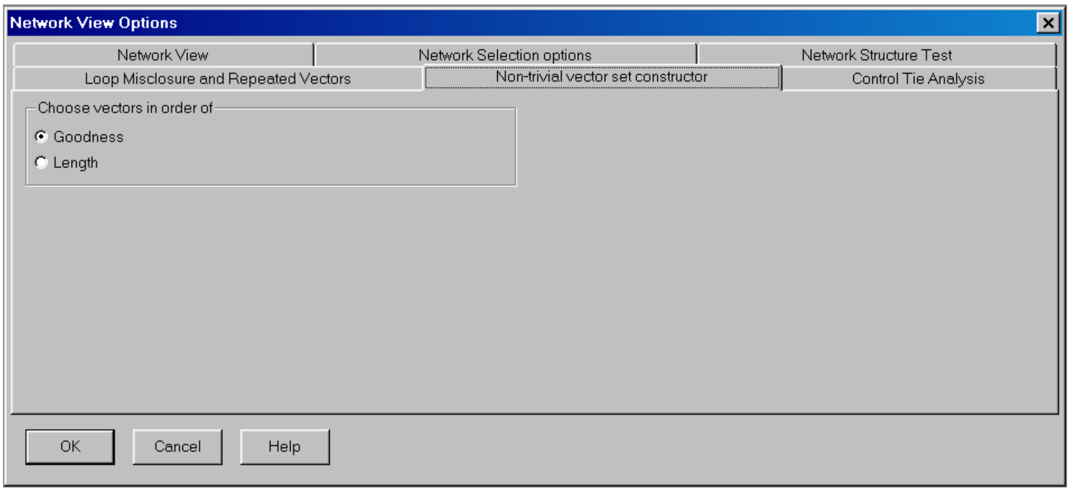


Figure 2-20

PINNACLE 1.0 provides two options (see Figure 2-20): the user may want to exclude from the trivial loop (and from further adjustment) either the longest or the 'least precise' vector. In the first case, the user will select ***Length*** from the ***Choose vectors in order of*** radio button group. In the second case the user will press the ***Goodness*** radio button. If ***Goodness*** has been chosen, the program will remove the loop vector with the largest rms position error[7].

Note that if a vector is *unprocessed*, PINNACLE 1.0 will set the vector's rms position error to infinity. For such vectors, only their lengths can be compared.

Below let's consider an example subnet of seven stations as shown in Figure 2-21 .

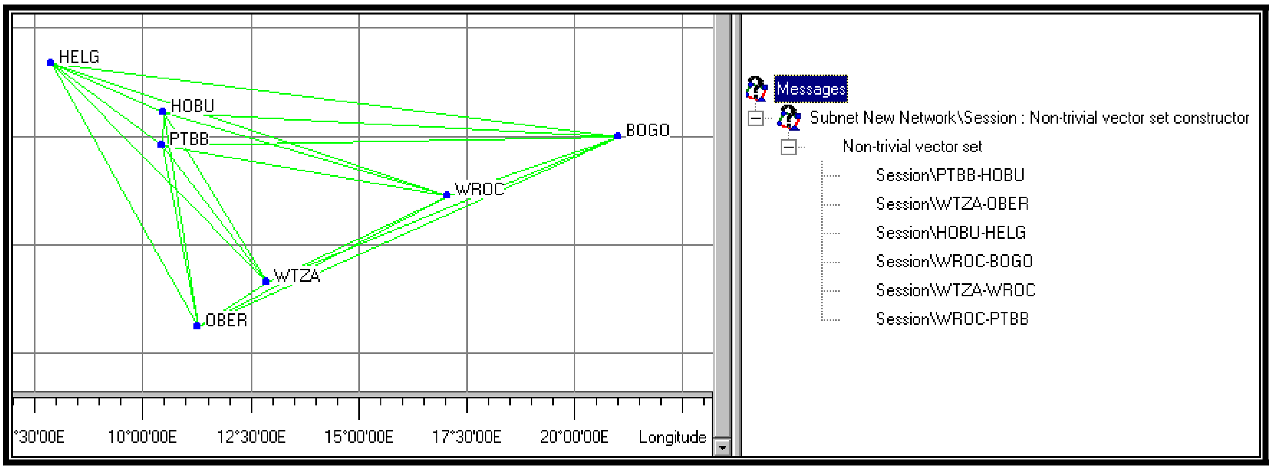


Figure 2-21

The raw data measurements have been collected at the seven sites simulteneously so that only six out of 21 vectors[8] will be identified as *non-trivial*. In this case the user is recommended to scale the final variances for the adjusted points by a factor of 3.5 (21/6).

---

[7]) The formula to compute the rms position error by using the variances is this:

rms position error = $\mathbf{sqrt(\sigma_x\sigma_x + \sigma_y\sigma_y + \sigma_z\sigma_z)}$

[8]) C(7,2) = 7!/2!/5! = 21

Pinnacle 1.0 allows a simple way to view non-trivial vectors in the *Network View* window. If the user clicks on a *non-trivial* vector in the analysis panel, this vector will be highlighted in a dark color in the *Network View* graph (see Figure 2-22).

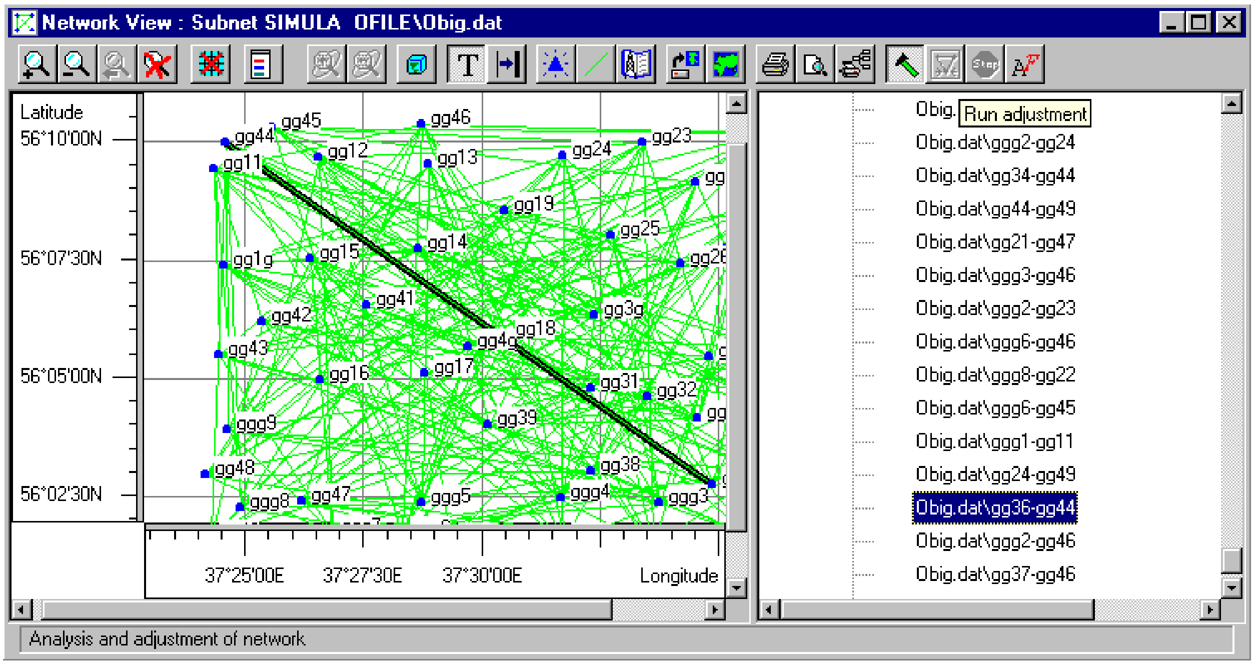


Figure 2-22

2.6. Control Tie Analysis

This test will check the consistency of the control applied. Given a pair of control points, this feature will compare the baseline's coordinates based on the control data with the processing coordinates computed by using the GNSS raw data. Usually, this test is run before starting the final adjustment. The test results will help the user estimate the real accuracy of the local control and find possible blunders in the reference coordinates or in attaching the control points.

It is not necessary to perform this test for the entire subnet. The *Test Selected* option is used to carry out the test for only selected vectors (recall that vectors can be selected through either *Subnets* or *Solutions*).

Note that all of the above mentioned options are also accessible through the *Network View Options* dialog window. To access them, right-click somewhere in the *Network View* window and select *Options* from the pop-up menu.

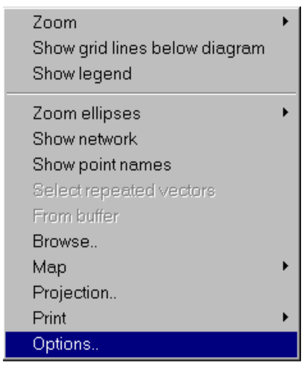


Figure 2-23

After the *Network View Options* dialog window is opened, select the Control Tie Analysis tab (see Figure 2-24).

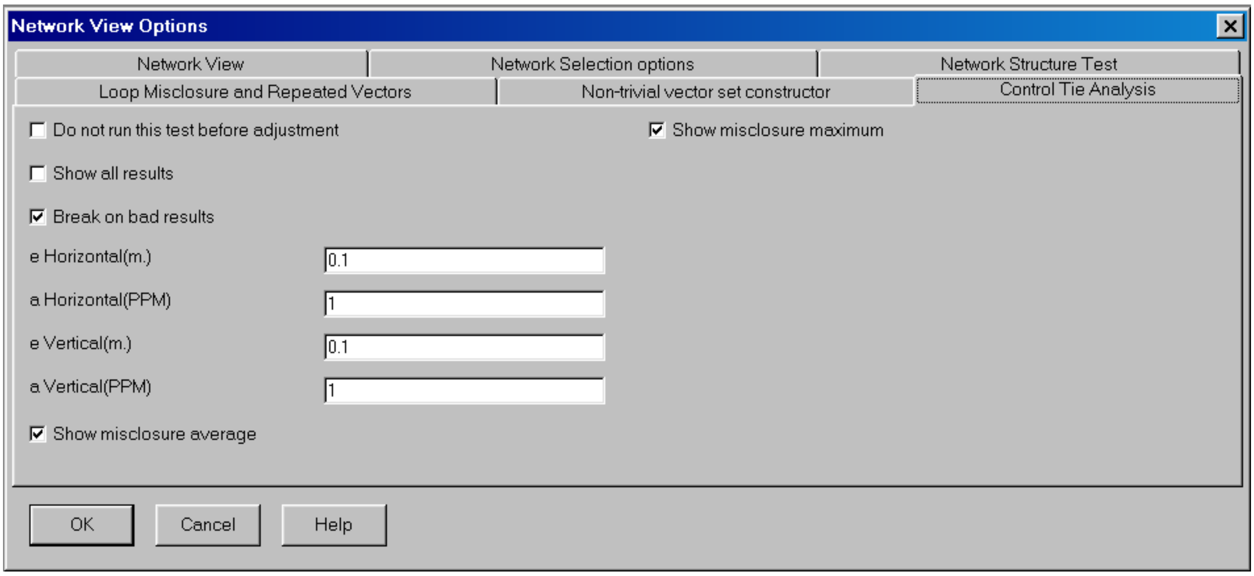


Figure 2-24

- The ***Do not run this test before adjustment*** checkbox allows the user to skip the *Control Tie Analysis* test at the pre-adjustment stage.
- The ***Show All Results*** checkbox indicates how the program will display the results of comparing the control coordinates of the vectors with their processing coordinates. (Note that this test is primarily intended to localize possible blunders in the specified control).

  If this checkbox is unchecked, the user will see[9] information only on the vectors whose processing coordinates are found *inconsistent* with the control specified for the end points (see Figure 2-25). Such vectors are referred to as *bad* and are marked with the warning icon.

  On the contrary, if the checkbox is selected, the user will see test results on both *bad* and *good* vectors (see Figure 2-26).
- The ***Break on bad results*** checkbox indicates how the program behaves if the *Control Tie Analysis* test fails. If this box is checked and the test fails to meet the specified tolerances, the program will interrupt further adjustment. If this box is unchecked, the program will continue even if the test is not passed.
- The ***a-Vertical*** / ***e-Vertical*** and ***a-Horizontal*** / ***e-Horizontal*** edit boxes are used to set the parameters governing the individual tolerances for vertical and horizontal misclosure errors, respectively. The tolerance equation is the same as shown in Section 2.4.
- The ***Show Misclosure Maximum*** and ***Show Misclosure Average*** checkboxes allow the user to display in the analysis panel the maximum and average values of the computed misclosure errors.

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[9]) under the 'Testing fixed points' node

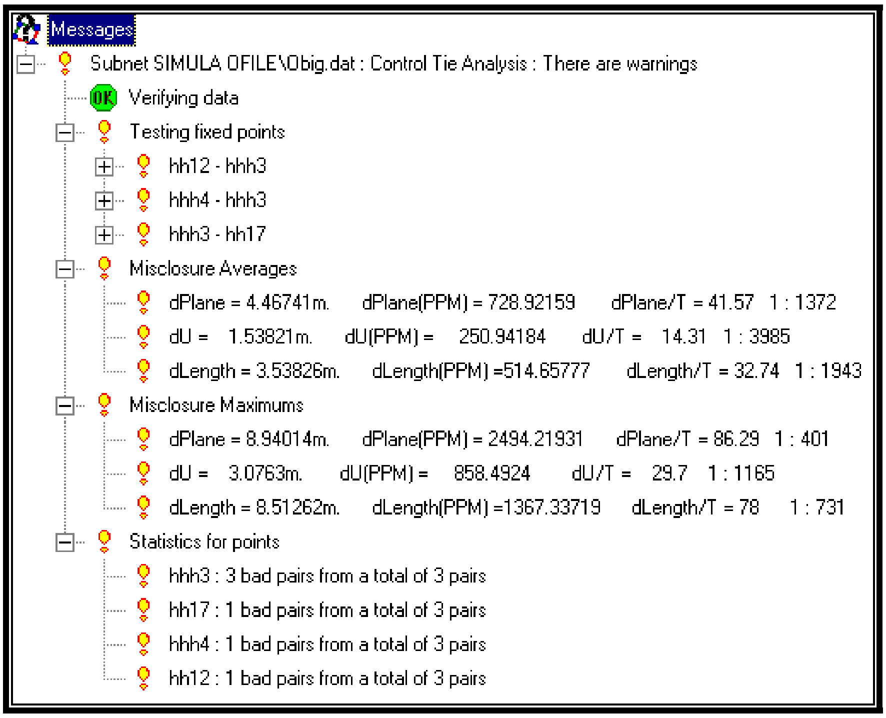


Figure 2-25

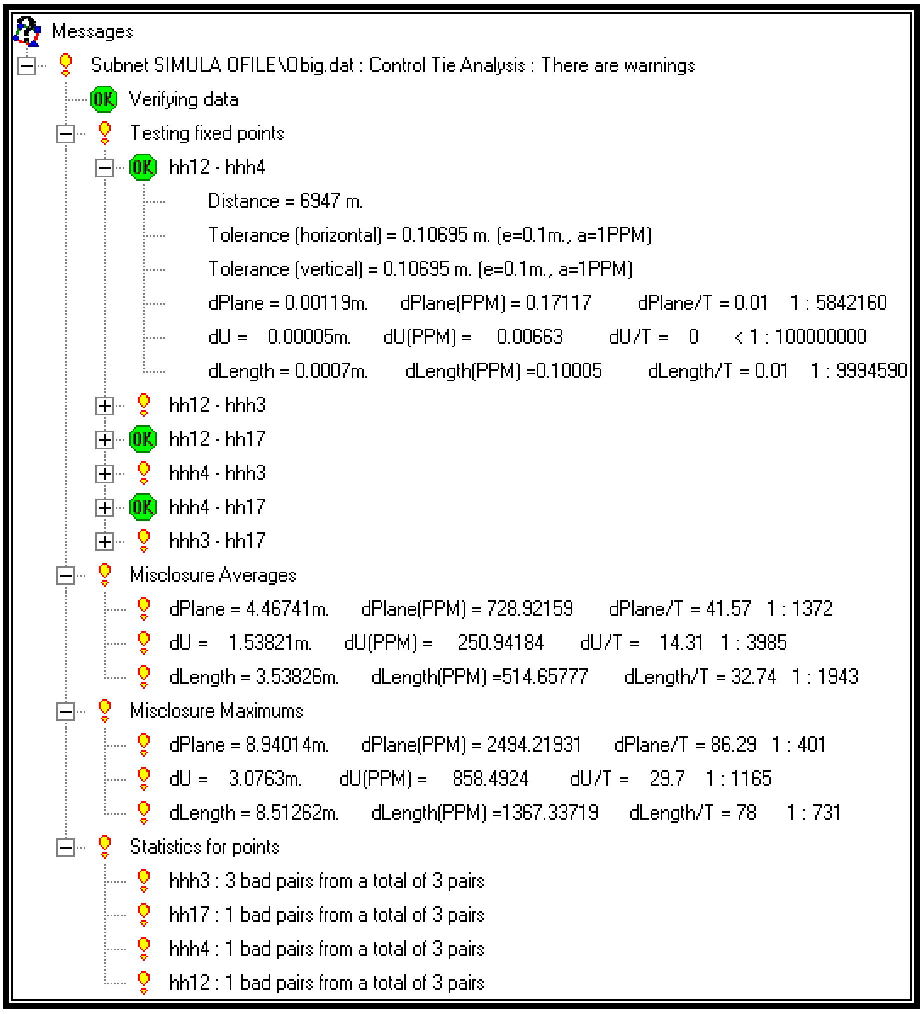


Figure 2-26

3. *Free or Minimally Constrained Adjustment*

To make outlier (blunder) detection more effective, the user should perform a minimally constrained adjustment of the given vector network. This type of adjustment is based on using only the subnet's *inner constraints.* Before a minimally constrained adjustment is run, a ***seed*** point must be set for the subnet adjusted. The user may or may not specify the seed point explicitly, i.e. by attaching control to one of the subnet's points. In the second case Pinnacle will select a seed point automatically.

When specifying a seed point, the user may use *fixed, weighted* or *mixed* control for this purpose. It is recommended (yet not required) that the same control data be used at the free and final (constrained) adjustment stages. Note that the coordinates of the adjusted points will not depend on whether the control is fixed or weighted (on the other hand, the estimated variances will depend on the selected type of control).

3.1. Setting Adjustment Parameters

To set up the desired adjustment parameters, right-click on the subnet when and select *Properties…* from the subnet's pop-up menu. When the *Properties for Subnet…* window is opened, select the *Parameters* tab. A dialog box will appear as shown in Figure 3-1. Select the desired adjustment parameters using the GUI controls as explained below.

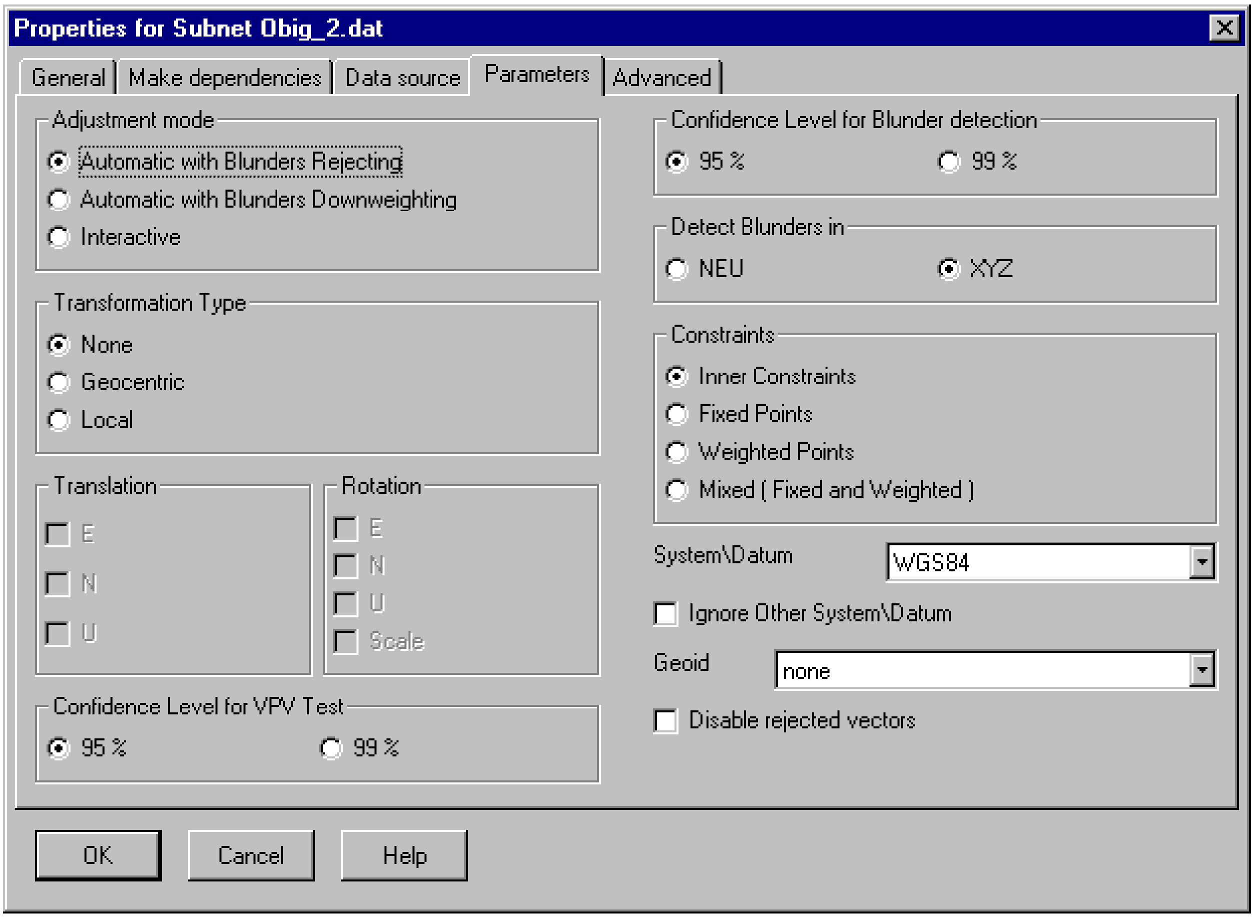


Figure 3-1

- In the ***Adjustment mode*** radio button group, select an adjustment mode, either *interactive* or *automatic*. The latter is based on either rejecting (***Automatic with***

Blunder Rejecting) or downweighting blunders (***Automatic with Blunder Downweighting***). Note that the default mode is ***Automatic with Blunder Rejecting***. For 'complicated' subnets we would recommend using the ***Interactive*** mode. For first-time users it is recommended to use the ***Automatic with Blunder Downweighting*** mode, which allows the user to maintain in the adjustment all of the available vector measurements.

- Select the ***None*** radio button from the ***Transformation Type*** group because no transformation parameters are estimated when running free adjustment.
- Select a confidence level (either 95% or 99%) for the 'global' V'PV-test (from the ***Confidence Level for V'PV Test*** radio button group) and the blunder detection test (from the ***Confidence Level for Blunder detection*** radio button group).

  Note that the 95% confidence level corresponds to a narrow confidence interval, i.e., this is a more strict condition for rejecting outliers (blunders) as compared to the 99% level. If the 99% confidence level (probability=0.99) is selected, fewer outliers (blunders) will be detected (rejected, downweighted).
- In the ***Detect Blunder in*** radio button group, select a coordinate system in which the program will search for possible blunders (either *NEU* or *XYZ)*.
- Choose ***WGS84*** for the ***System/Datum*** field to indicate that adjustment will be performed in the WGS84 datum.
- Select ***None*** from the ***Geoid*** list box to indicate that no geoid data will be used in the adjustment.
- In the ***Constraints*** radio button group, select ***Inner constraints***.

Use the ***Disable rejected vectors*** checkbox to define the status of vectors rejected in the course of adjustment. If this checkbox is checked, then, for the given subnet, all the vectors rejected in the current adjustment iteration will be *disabled* (not used) in further adjustment iterations (unless their status is manually changed from *disabled* to *enabled*). This is done by right-clicking on the desired vectors in the network view graph and toggling their status.

Note: Once a vector is rejected and therefore disabled (in accordance with the *Disable rejected vectors* checkmark), the user *will not be able* to switch this vector's status back to *enabled* in the succeeding iterations merely by unchecking this checkbox.

3.2. Handling Outliers/Blunders in Different Modes

After setting the above parameters, get back to the *Subnet* menu and select *Run Adjustment.* The *Network view* window will be opened displaying the *Network View* graph on the left and the *Analysis panel* on the right. The analysis window will show all of the messages generated at the pre-adjustment and adjustment stages. If necessary, either part of the adjustment window can be resized by moving the splitter left or right.

If either of the two ***Automatic*** adjustment modes is selected, the program will search for and process possible blunders without operator intervention.

If ***Interactive*** is selected, the *user* will reject or downweight the detected outliers/blunders (if any). To handle the outliers/blunders identified, the *Blunder detection results* dialog window is used. It will list all suspect vectors (see Figure 3-2).

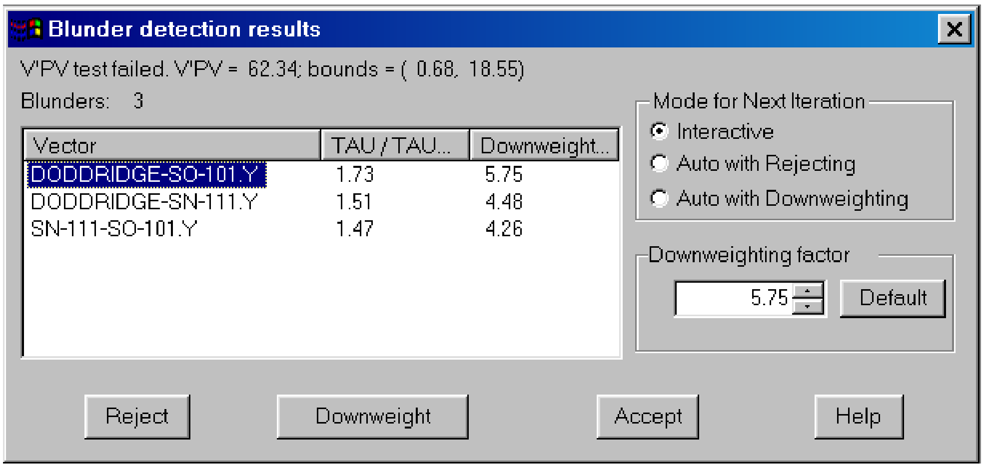


Figure 3-2

This dialog window provides the following information:

- V'PV-test results (the value of the statistic and the bounds of the confidence interval);
- Names of the suspect vectors. The rightmost character in the *Vector* column indicates which of the vector's components is worst (i.e., which component has the largest error). This character can be N, E, or U for a local system; or X, Y or Z for an XYZ coordinate system.
- Tau / Tau_{crit} ratios for bad vector components together with the recommended downweighting coefficients. Recall that $Tau = Res / \sigma_{Res}$, where *Res* designates the residual calculated for the corresponding measurement and σ_{Res} stands for the rms residual error. Also note that the denominator Tau_{crit} will only depend on the number of degrees of freedom (this parameter will range between 3 and 5 for most practical cases). Also note that the downweighting coefficients are always equal to $e^{ABS(TAU)/TAU\ crit}$ (unless the user changes the default values, see below).
- Downweighting factors recommended. The user may disregard the recommended values entering some alternative downweighting factors.

Now, press the ***Downweight*** button to enable the downweighting factors specified for the suspect vectors and to start the next adjustment iteration.

Note that it is usually ***not*** recommended to downweight a group of suspect vectors at a time. Rather, the user should downweight suspect vectors one by one selecting in the current step the vector with the largest Tau / Tau_{crit} ratio.

In addition, the user may want to reject one or more erroneous (suspect) vectors. The user should reject erroneous vectors one by one selecting in the current step the suspect vector with the largest ratio. To do this, the user will highlight the required item in the suspect vector list and then press the ***Reject*** button.

Note that in the following iteration the program may well detect some new suspect vectors. The user should keep in mind that an interactive adjustment will be finished only when no more new suspect vectors are found.

If the ***Accept*** button is pressed, all of the vectors that have been identified as outliers/blunders will be used in the adjustment as if they are correct measurements.

Also note that prior to starting another iteration, it is possible to update the adjustment mode switching for example from *Interactive* to *Automatic*.

Each suspect vector detected will be marked in a unique color in the network view graph depending on the action chosen. Specifically, rejected and downweighted vectors will be marked in red and magenta color respectively. If the user selects “Accept”, the vector will be drawn in green.

If necessary, the user may stop the current adjustment iteration by pressing the toolbar's *Stop* button  in the *Network View* window. In this case the intermediate adjustment results will not be saved.

To briefly describe the adjustment results obtained, some basic information will be displayed in the *Analysis* panel. To get detailed information on the adjustment results, run the corresponding adjustment report(s). To do this, open the subnet’s context menu and select the *Report...* option (see [2]).

4. *Final Adjustment or Adjustment Using Local Control*

The constrained adjustment stage finalizes the initial stages described above. This type of adjustment is performed to fit a given GNSS vector network (subnet) to local control. Control data (specifically, control points' positions) is used as constraints.

In spite of good GNSS measurements and high estimated accuracy of free adjustment results, you are not able to get the points' positions (after performing a constrained adjustment) with accuracies higher than that of the local control. As a rule, GNSS measurements' accuracy is much higher than the accuracy of measurements conventionally used for creating the local geodetic networks. Consequently, the free adjusted network is more rigorous than the network adjusted using the local control. In the course of constrained adjustment, the local control's errors and distortions may badly affect the adjusted network's accuracy. If this occurs, the standard error of unit weight will increase considerably. The a posteriori standard error of unit weight may change a bit, but it should not change appreciably. If it does, you should check the local constraining control used. Nevertheless, this adjustment type is the only way to 'submit' a new built network to the specific local datum. In this final stage of adjustment, the GNSS vector network must be constrained by more than one local control point (see[1] for how to handle control data). It is necessary to constrain the network by at least two horizontal control points and three vertical control points but, as a rule, redundant constraints are used. If the transformation parameters are computed in the course of adjustment, the necessary number of control points should be increased depending on the number and type of the unknown parameters. There is a simple empirical rule to compute a sufficient number of control points used in a constrained adjustment. It is recommended that the percentage of control points used in a network should not be below 10%. After the the constrained adjustment is finished, the coordinates of *all* of the network points will be presented in the local system (datum).

It is strongly recommended to start a constrained adjustment only after the pre-adjustment and free adjustment stages have been successfully completed. The following is a detailed description of the constrained adjustment stage.

4.1. Selecting Control Data Lists for Adjustment

To select control points for an adjustment, open the subnet's context menu and choose the *Attach control point* option. The *Select control data lists* window will be opened, which shows the *control data lists* available in the system (see Figure 4-1).

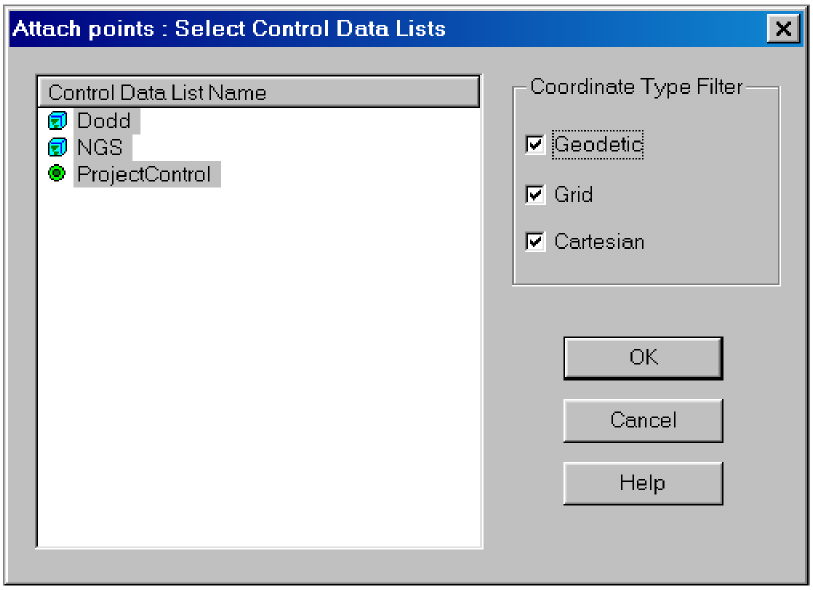


Figure 4-1

Note that control data lists located in the project root will be marked with the green circle . These lists are available for all networks in the given project. Control data lists belonging to individual networks will be marked with the blue cube .

The ***Coordinate Type Filter*** checkbox group allows the user to disable unnecessary coordinate types when displaying control data in the *Attach points to Control Point Items* window.

After the desired lists have been selected, the *Attach points to Control Point Items* window will be opened (see Figure 4-2).

This window allows the user to attach control data to a GNSS network even if some survey points and control stations related to them have *different* names. The *Points to attach* list will show the names of the subnet's points. The *Control point items* list will show the control points selected for the survey area (recall that the program will display only the control data meeting the *Coordinate Type Filter* settings).

4.2. Attaching Control Data to a GNSS Subnet

To attach control data to a GNSS subnet, click on any of the subnet's points in the ***Points to attach*** list. The ***Control point items*** list's points will be automatically rearranged in accordance with their distance from the user-specified subnet point, starting with the closest control point.

Note that even when a GNSS point and a control point refer to the same physical monument, the distance shown in the *Control point items* window may be up to several meters[10] in magnitude since this value is computed by using the point’s coordinates relating to different datums.

10) On rare occasions this value can be up to a few *hundred* meters

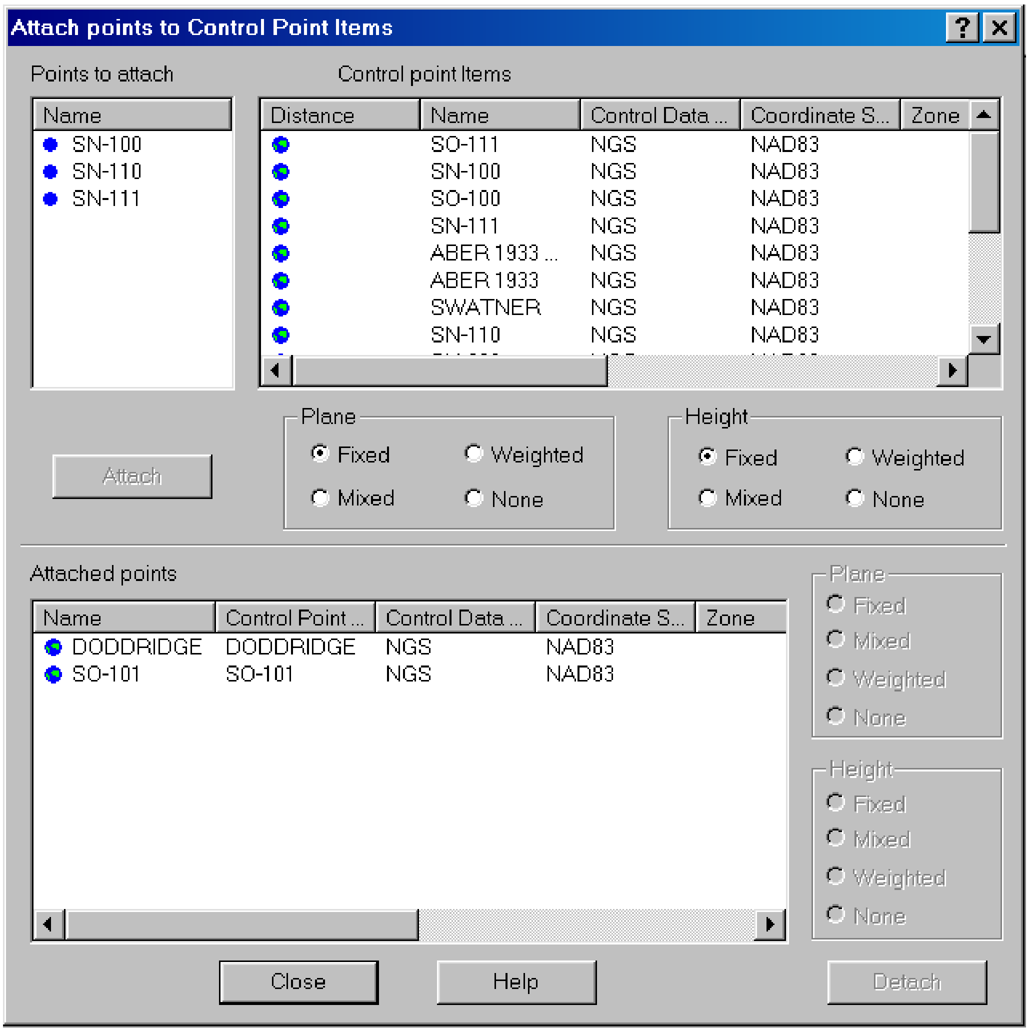


Figure 4-2

Next, the user should move the cursor onto the appropriate line (as a rule, this is the very first line in the list), place the cursor on the distance icon and click on it. By doing this, a connection between the survey point and control point is established and the ***Attach*** button becomes accessible.

Before pressing the *Attach* button, the user should define the status of the subnet's control data. With the help of the ***Plane*** and ***Height*** radio button groups, the user may fix or weight a control point's plane or height components.

If ***Fixed*** is selected, the point's coordinate(s) will be treated as fixed when performing a constrained adjustment. If ***Weighted*** is selected, control data will be weighted according to the standard error specified (see [1] the *Properties for Item of Control Point …* window). If the user chooses ***Mixed***, control data will be treated as either fixed or weighted depending on the adjustment type selected (see Section 1.3.4 below). If the user selects ***None***, the corresponding control data will not be used in the adjustment.

After defining the control data status, press the ***Attach*** button. The associated pair *“GNSS survey point — control point”* will be saved to the project's database. In the *Attach points to control point items* window, this pair will be moved down to the ***Attached points*** box. The corresponding GNSS point will be marked in the *Network view* with a blue triangle (for horizontal control) and/or with a blue square (for vertical control).

Additional control may be attached to survey points in the same manner.

The upper half of the *Attach points to control point items* window will maintain only those survey points that either do not have appropriate control or, for some reason, have not been attached to the control data available.

The status of the attached control data may be changed, for example, from *Fixed* to *Weighted*. The user may want to detach control points. To do this, choose the desired point from the *Attached points* list and then use the appropriate checkboxes from the right of the list, or press the ***Detach*** button in the bottom right-hand corner of the *Attach points to control point items* window. Detached points will be replaced in the upper half of the window. Note that, once detached, subnet points are no longer marked as "attached" in the network view.

Also, the user is able to change the status of any control point in the *Network View* window. To do this, right-click on the desired point and choose the *Attach Control Point* option from the pop-up menu that appeares. To change the status of a set of points, highlight the points in the network view by clicking on them while pressing down the *Shift* or *Ctrl* button and then right-click on any highlighted point.

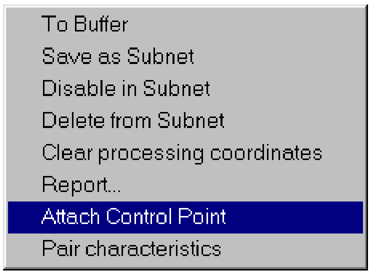


Figure 4-3

Activating the *Attach Control Point* option provides the *Attach points to Control Point Items* window that only maintains the selected points.

4.3. Control Tie Analysis

After control data are attached, it is worth comparing the relative positions of the control points with the relative positions of the corresponding subnet points. This allows the quality estimation of the given local control, the earliest possible detection of major errors both in control data (e.g., typos in printed catalogues) and GNSS measurements (e.g., incorrect or misused antenna height) as well as slips in attaching the control data to the subnet's points.

For how to perform the control tie analysis test, refer to 2.6.

4.4. Setting Adjustment Parameters

Open the subnet's context menu and select *Properties*. The *Properties for Subnet…* window will open. Choose the ***Parameters*** tab and a dialog window featuring the adjustment parameters will open (see Figure 4-4).

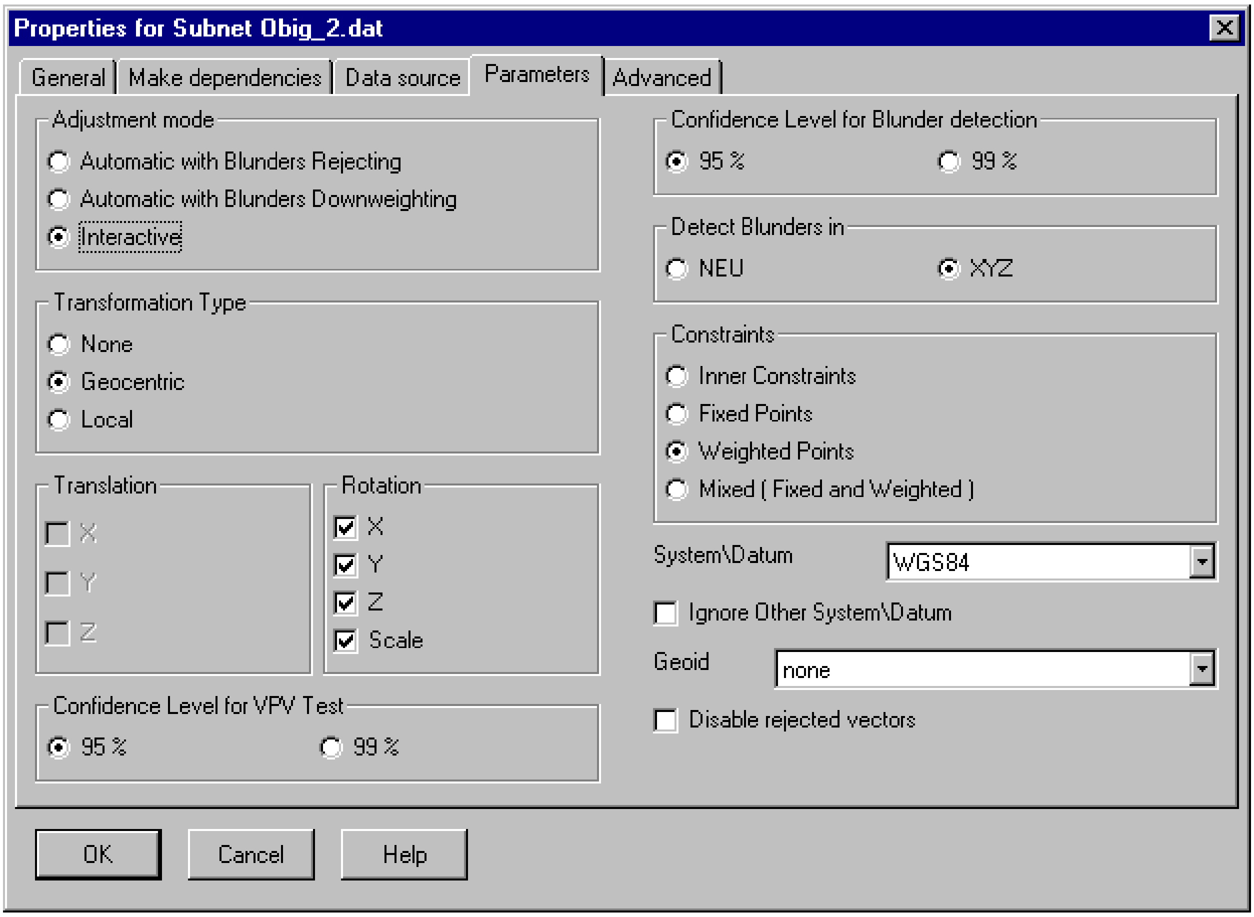


Figure 4-4

In the ***Adjustment mode*** radio button group specify which adjustment mode will be applied — *Interactive, Automatic with Blunder/Outlier Rejecting* or *Automatic with Blunder/Outlier Downweighting*. For large and complicated subnets it is recommended to use '***Interactive'*** mode.

In the ***Constraints*** radio button group, choose among *Fixed points*, *Weighted points* and *Mixed (Fixed and Weighted)*.

If ***Fixed points*** is selected, the adjustment will be constrained by control data whose status is either *Fixed* or *Mixed* (see the *Properties for Item of Control Point …* window).

If ***Weighted points*** is selected, the adjustment will be based only on weighted control, that is, only those control points will be used whose positions are defined as *Weighted* or *Mixed*.

If ***Mixed (Fixed and Weighted)*** is selected, control points whose status is either *Fixed* or *Mixed* will be used as fixed, and those, marked as *Weighted*, will be used with the appropriate weights applied.

Table 1 shows how a control point will be used in adjustment depending on the point's status and the selected 'Constraints' option.

Table 1

#	*Status of control point*	*'Constraints' option selected*	*Control will be used in adjustment as*
1	Fixed	Inner Constraints	None
2	Weighted	Inner Constraints	None
3	Mixed	Inner Constraints	None
4	None	Inner Constraints	None
5	Fixed	Fixed Points	Fixed
6	Weighted	Fixed Points	None
7	Mixed	Fixed Points	Fixed
8	None	Fixed Points	None
9	Fixed	Weighted Points	None
10	Weighted	Weighted Points	Weighted
11	Mixed	Weighted Points	Weighted
12	None	Weighted Points	None
13	Fixed	Mixed (Fixed and Weighted)	Fixed
14	Weighted	Mixed (Fixed and Weighted)	Weighted
15	Mixed	Mixed (Fixed and Weighted)	Fixed
16	None	Mixed (Fixed and Weighted)	None

The ***System\Datum*** list box is used to specify the coordinate system in which the data is adjusted and then presented in the corresponding adjustment report.

If the ***Ignore other system\datum*** checkbox is checked, the adjustment engine will omit any control data specified in a coordinate system different from that selected with the *System\Datum* listbox.

From the ***Geoid*** list box, the user selects the geoid model that will be used to convert between ellipsoidal and orthometric heights. The user may choose a global, regional or local (derived by PINNACLE 1.0 by using GNSS data) geoid model. If ***None*** is selected, then the *geoid* is considered coincident with the *ellipsoid*, that is, the actual geoid undulation is neglected (specifically, zeros will be used for geoid heights when adjusting the data). Note that the ***None*** option may be used with good results only when the given survey area is fairly small and the geoid is assumed flat over this area.

In the ***Transformation Type*** radio button group, the user will specify what transformation parameters, if any, will be estimated in the course of adjustment (a transformation between the WGS84 datum and the local datum specified in *System\Datum* is what is meant here). If ***None*** is selected, no transformation parameters will be estimated. If the user chooses ***Geocentric*** or ***Local***, four transformation parameters — a ***scale factor*** and three ***rotation angles*** — will be determined. If the ***Geocentric*** radio button is selected, the rotation angles will be determined with respect to the XYZ axes. If the *Local* radio button is used, the rotation angles are determined relative to the local system's NEU axes. Once either *Geocentric* or *Local* is selected, the ***Rotation*** group's checkboxes, which are associated with the rotation angles and scale factor, will become accessible. By using these checkboxes, the user may define the desired combination of transformation parameters to be estimated in the course of adjustment (note that these parameters will be treated as "additional" unknowns when adjusting data). In case there is not enough control data to determine the checked transformation parameters, the adjustment will stop and a warning message will be displayed.

When running the final adjustment it is recommended to estimate the transformation parameters together with the other unknowns because otherwise the adjustment results may not be good enough even though the GNSS measurements and local control are of good quality. When merging a newly created GNSS subnet into an existing high-order geodetic network (for example, a fiducial network), we recommend using the ***Geocentric*** option. If the local control has been created based on some conventional land-surveying techniques, the option ***Local*** is preferable since this allows for better compensation of possible regional distortions in scale and directions. Using the NEU system is therefore more 'convenient' since the user can estimate and/or fix individual rotation angles separately. Furthermore, the user can also separately handle the scale and rotations.

To fine-tune the adjustment process, press the ***Advanced*** **tab** from the *Properties for Subnet…* window (see below).

In this dialog window, the user may update the a priori errors of unit weight (UWEs) applied to both the vector network and control points. Care should be taken in updating the UWEs properly. The user is supposed to have ***enough*** information on the weights before changing them. This information might be:

- a posteriori UWEs estimated in the course of adjustment
- qualitative information on the control used
- intermediate results obtained in the previous iterations, etc.

Also, if such a priori information exists, the user may specify the magnitude of the lower and upper bounds for a transformation parameter determined. This can be done with the ***Transformation parameter constraints*** group (see Figure 4-5).

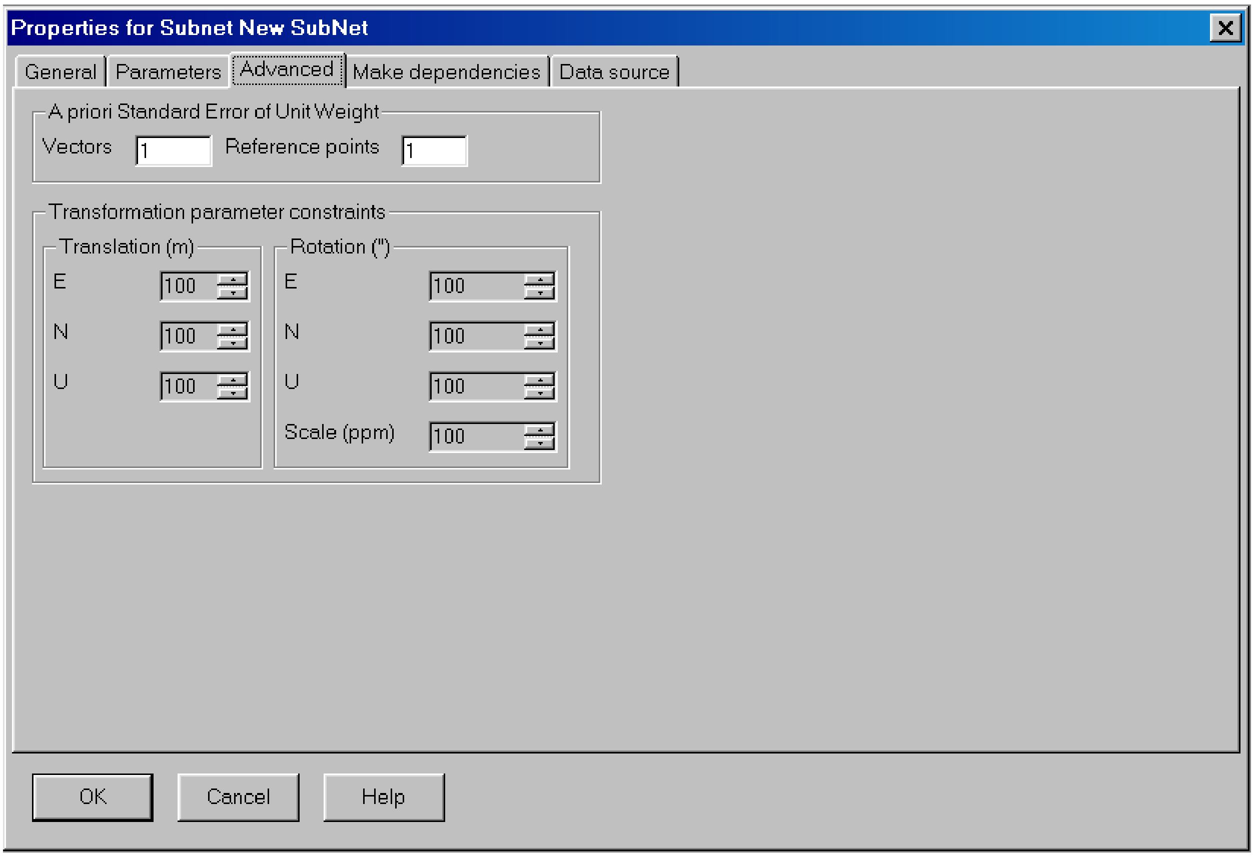


Figure 4-5

After all necessary adjustment parameters have been set, a final constrained adjustment can be started. This looks very much like running a minimally constrained adjustment. Note that there is one new feature here.

If the user chooses the *Interactive* adjustment mode and some of the control positions being used are marked as *Weighted,* the *Point Blunders* dialog window will be opened showing all the blunders/outliers detected, if any (see Figure 4-6):

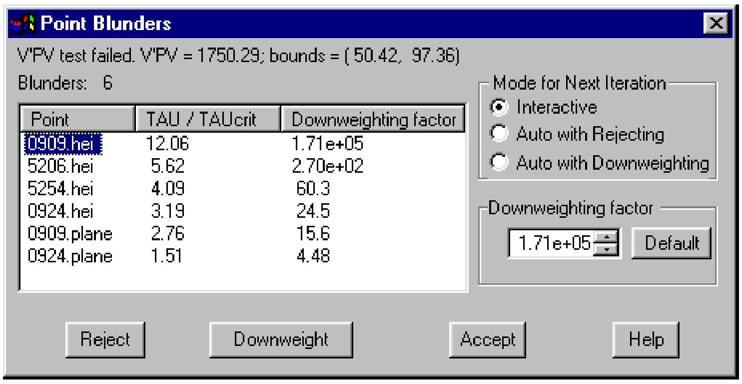


Figure 4-6

This window will display the names of the points that have been identified as 'blunders' (outliers). A suffix will be appended to the suspect point's name indicating whether the error is detected in plane (**.plane**) or in height (**.hei**). Also the computed ***Tau*** / $\textbf{\textit{Tau}}_{crit}$ ratios will be displayed together with the downweighting factors recommended for the next adjustment iteration (to compensate for the detected suspect data). These recommended (also referred to as "default") downweighting factors may be modified through the ***Downweighting factor*** edit box, if necessary.

The *Default* button is used to retrieve the initially recommended (default) downweighting factors.

As for the blunder-induced erroneous points, such points may be rejected, or downweighted (according to the value specified in *Downweighting factor)*, or accepted "as they are" (the latter means that the bad points are used as if they are perfectly correct). To run any of these three options, press the corresponding button at the bottom of the window: *Reject, Downweight* or *Accept.*

The points whose control data have been rejected or downweighted in the course of adjustment will be marked in the *Network view* graph in **red** and **magenta**, respectively. Note that horizontal and vertical components will be handles *separately*.

Once the user has finished editing erroneous data, the program will start another adjustment iteration and a new *Point blunders* dialog window will be displayed if another blunders are found.

The user may stop the iterative process and run automatic adjustment mode by selecting either of the *Auto with rejecting* and *Auto with downweighting* radio buttons from the ***Mode for Next Iteration*** group.

Sometimes it is necessary to stop the current adjustment iteration. It can be done by pressing the toolbar's *Stop*  button. Note that the intermediate adjustment results will be lost in this case.

When the constrained adjustment is over, the program will display several messages ("adjustment summary") in the *Analysis* panel. Detailed information on the adjustment results can be found in the corresponding adjustment report. The report may be obtained by opening the subnet's context menu and selecting *Report…* (see [2]).

5. *Displaying&Reporting Adjustment Results*

The following data is available when a subnet's adjustment is over:

- pre-adjustment results
- adjustment results

5.1. Pre-adjustment Test Results

Results of the *SubNet structure*, *Loop Misclosure and Repeated Vectors* and *Control Tie Analysis* tests will be displayed in the *Analysis panel* of the *Network View*. These results are accessible as long as this window remains open. Note that the pre-adjustment test results can also be saved to a text or hypertext file. To do this, right-click on the node of interest (for example, "Testing loop Misclosures") in the *Analysis* panel and select the *Save to file* command from the pop-up menu (see Figure 5-1).

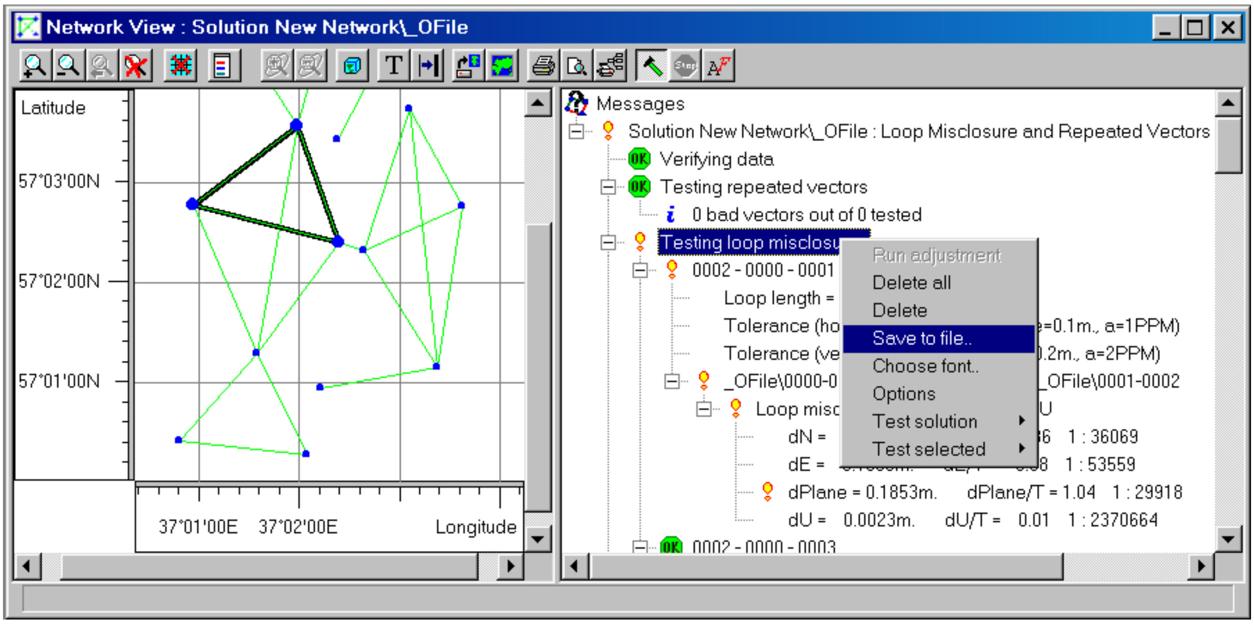


Figure 5-1

After that, a standard File|Save dialog box will appear prompting the user to save the data as a text (*.txt) or hypertext (*.html) file.

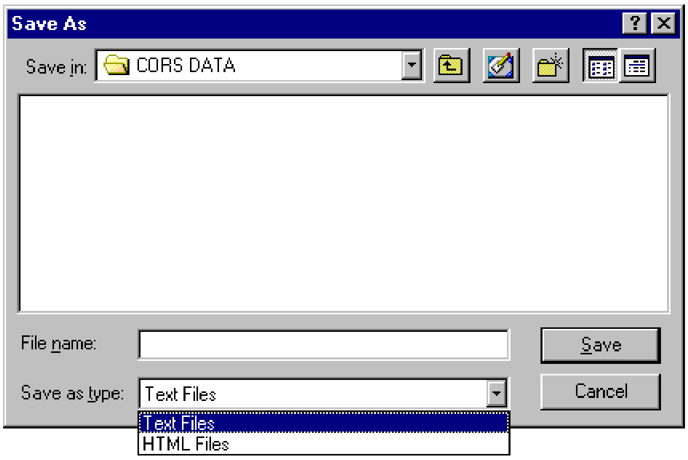


Figure 5-2

Once such a file is created, the user can open it and view the file data as usual, for example:

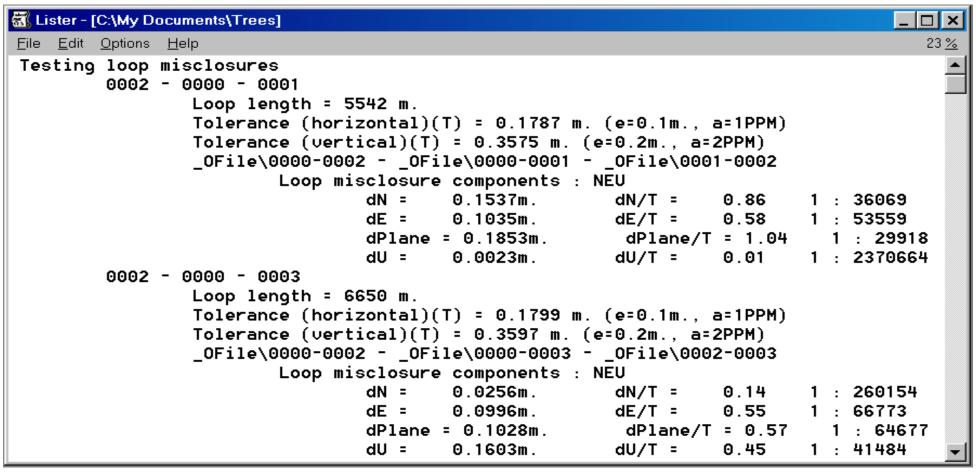


Figure 5-3

5.2. Adjustment Results

Adjustment results will comprise *brief results*, *diagrams*, *adjusted baselines*, *adjusted network statistics, and reports*.

5.2.1. Brief results

Brief results will be displayed in the *Analysis* panel. They will include the following general information about the adjusted subnet:

- Blunders/outliers detected and downweighted (or rejected altogether)
- V'PV statistic
- Statistical analysis of the computed residuals, etc.

These results will be available as long as the *Network View* window remains open. Also, they can be saved to disk as a text or hypertext file in exactly the same way as it is done for pre-adjustment test data.

5.2.2. Diagrams

For some of the adjustment results, it will be much more informative to present them in a graphical form. PINNACLE 1.0 enables the user to graphically present the following data types:

- Residuals distribution histograms
- Diagrams of the *relative positioning accuracy* for the adjusted points.

To open the *Diagrams…* window, the user will select the *Diagrams…* option from the subnet's menu (see Figure 5-4).

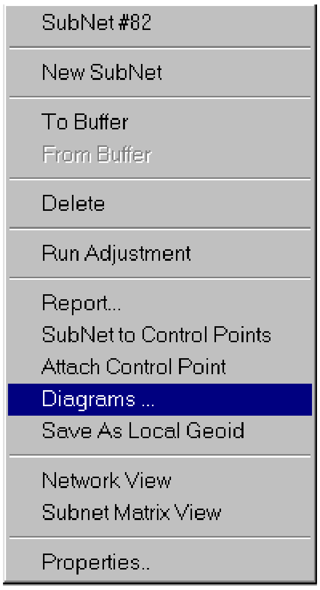


Figure 5-4

Select the desired diagram type(s) from the list (see Figure 5-5) and press the *OK* button.

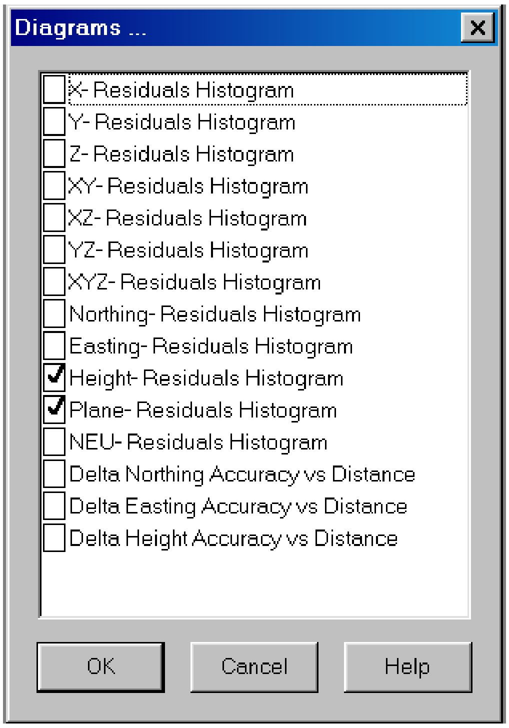


Figure 5-5

In this way as many different diagrams can be opened as needed.

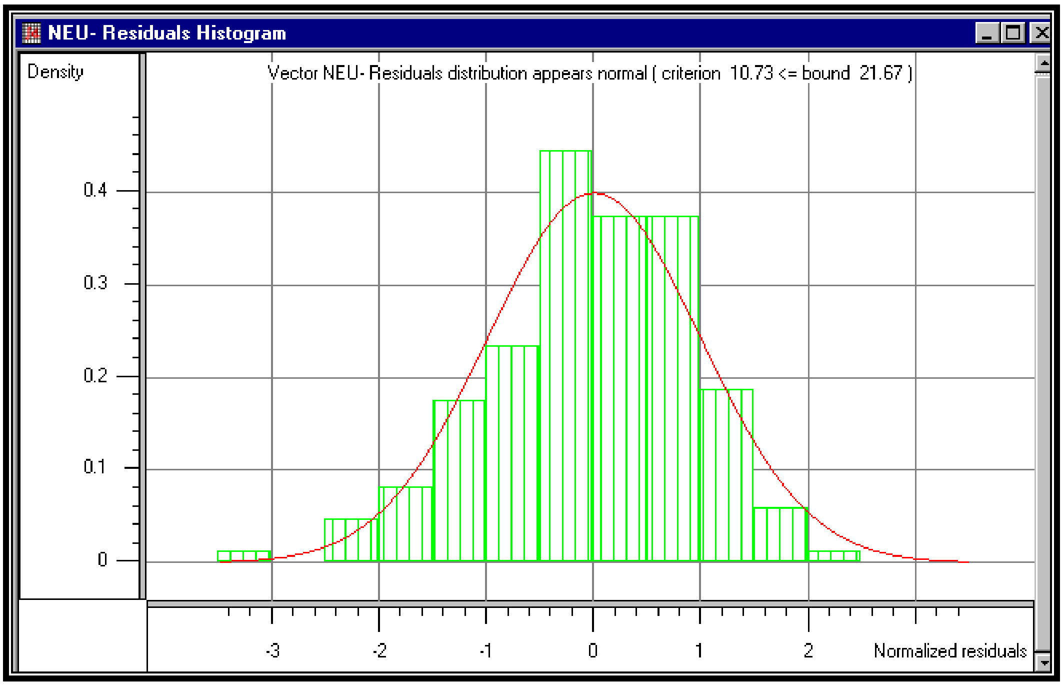


Figure 5-6

Note that the histograms ***XYZ- Residuals*** and ***NEU-Residuals*** and the diagrams ***Delta Northing Accuracy vs Distance***, ***Delta Easting Accuracy vs Distance*** and ***Delta Height Accuracy vs Distance*** are also available as adjustment reports (see [2]).

5.2.3. Adjusted baselines

PINNACLE 1.0 provides information on all of the baselines associated with the points of the adjusted subnet. These baselines do not necessarily coincide with the "*GNSS-measured*" vectors.

Baselines may be presented in a ***XYZ***, ***NEU***, ***Latitude-Longitude-Height*** or ***Azimuth-Elevation-Distance*** coordinate system. PINNACLE 1.0 provides not only the baselines' coordinates but also their rms errors.

In the *Network View* graph, click on the first endpoint, and then click on the second endpoint while holding down *Ctrl* or *Shift* key. Next, right click on either endpoint and select the *Pair characteristics* option from the pop-up menu as shown in Figure 5-7 and Figure 5-8:

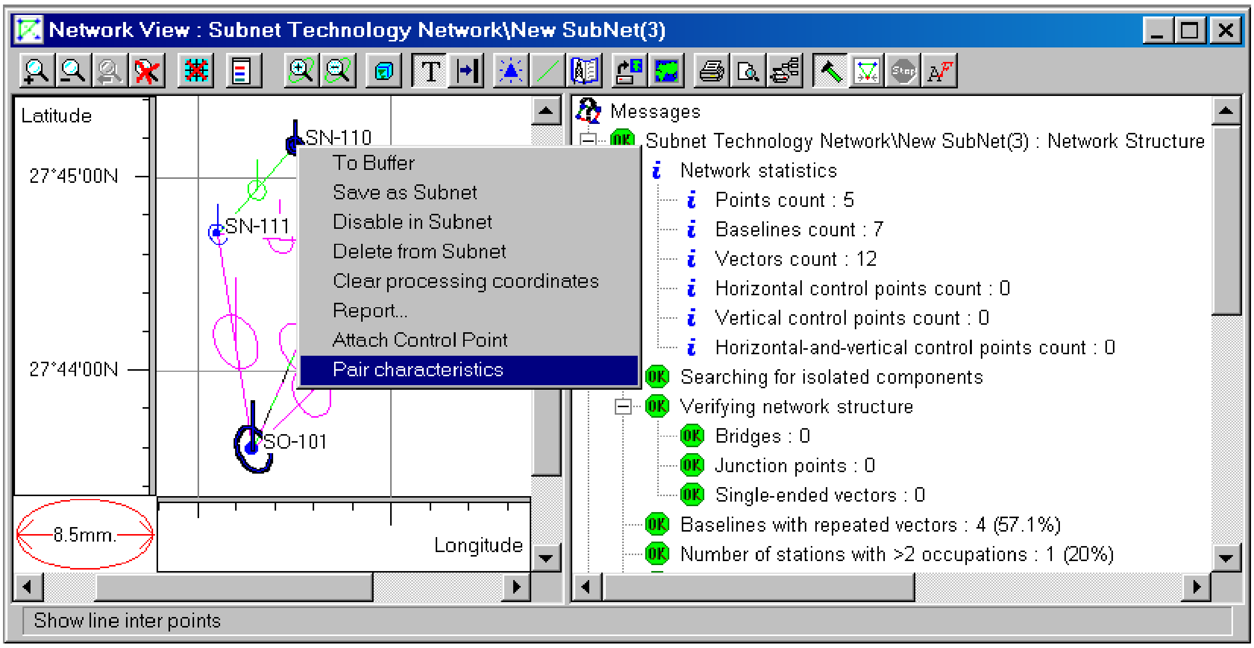


Figure 5-7

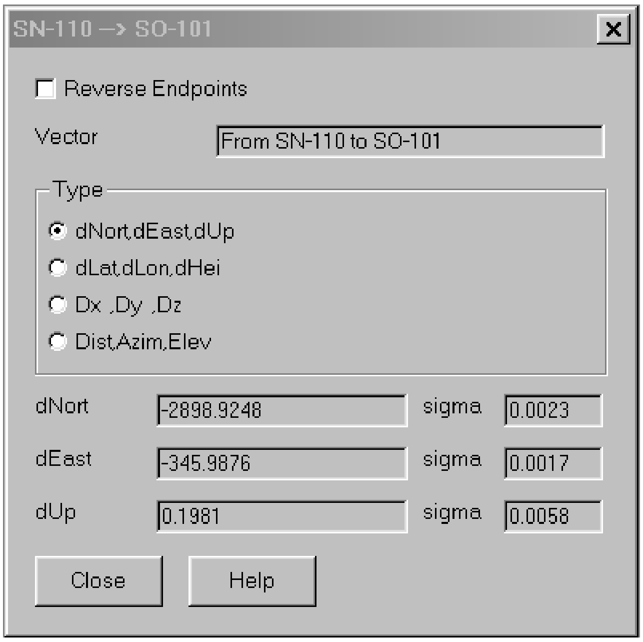


Figure 5-8

The endpoints' names (*From … to …*) of the selected baseline will be displayed in the ***Vector*** field.

The ***Reverse Endpoints*** checkbox allows the user to reverse the baseline's direction, i.e., ‘swap’ the vector’s endpoints. If this box is checked, the information in the *Vector* (*From … to …*) field will be changed correspondingly.

To set the desired coordinate system, select the corresponding option from the ***Type*** radio button group.

The rms errors are given in meters.

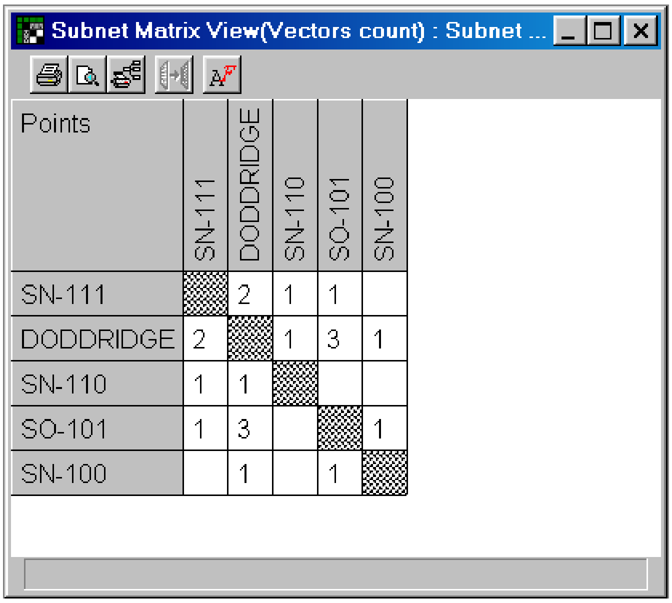
5.2.4. Adjusted Network Statistics

PINNACLE 1.0 allows the user to view the *adjusted subnet statistics*.

Select the *Subnet Matrix View* option from the subnet's pop-up menu. The *Subnet Matrix View* window will be opened.

By default, this window features only the subnet's *<u>GNSS measured</u>* vectors. The following statistical information is presented in this window:

- Total number of vectors measured (repeated vectors will be taken into account too)



Points	SN-111	DODDRIDGE	SN-110	SO-101	SN-100
SN-111		2	1	1	
DODDRIDGE	2		1	3	1
SN-110	1	1			
SO-101	1	3			1
SN-100		1		1	

Figure 5-9

- Covariance matrix of the adjusted subnet

Subnet Matrix View(Covariance matrix(mm^2)) : Subnet Technology Network\New SubNet

Points	SN-111			DODDRIDGE			SN-110			SO-101		
SN-111	170.39	4.1221	258.64	-95.962	-2.3738	-146.33	170.26	4.1308	258.54	167.4	4.4346	258.29
	4.1221	83.772	5.3208	-2.3834	-47.072	-2.9808	4.1213	83.695	5.3963	4.42	82.264	5.0411
	258.64	5.3208	659.82	-136.21	-2.8524	-344.26	258.65	5.4585	658.93	258.06	5.0743	641.84
DODDRIDGE	-95.962	-2.3834	-136.21	54.194	1.3572	77.039	-96.038	-2.3666	-136.17	-94.859	-2.4906	-136.16
	-2.3738	-47.072	-2.8524	1.3572	26.545	1.5742	-2.3481	-47.149	-2.6973	-2.484	-46.554	-2.7617
	-146.33	-2.9808	-344.26	77.039	1.5742	180.8	-146.35	-2.8569	-345.21	-146.1	-2.897	-338.79
SN-110	170.26	4.1213	258.65	-96.038	-2.3481	-146.35	170.98	3.9861	258.64	167.27	4.4337	258.31
	4.1308	83.695	5.4585	-2.3666	-47.149	-2.8569	3.9861	84.416	4.1952	4.4289	82.187	5.1787
	258.54	5.3963	658.93	-136.17	-2.6973	-345.21	258.64	4.1952	667.79	257.97	5.1515	640.94
SO-101	167.4	4.42	258.06	-94.859	-2.484	-146.1	167.27	4.4289	257.97	168.64	4.3123	258.44
	4.4346	82.264	5.0743	-2.4906	-46.554	-2.897	4.4337	82.187	5.1515	4.3123	82.782	5.1293
	258.29	5.0411	641.84	-136.16	-2.7617	-338.79	258.31	5.1787	640.94	258.44	5.1293	647.17

Figure 5-10

- 95% (99%) circular error probable;

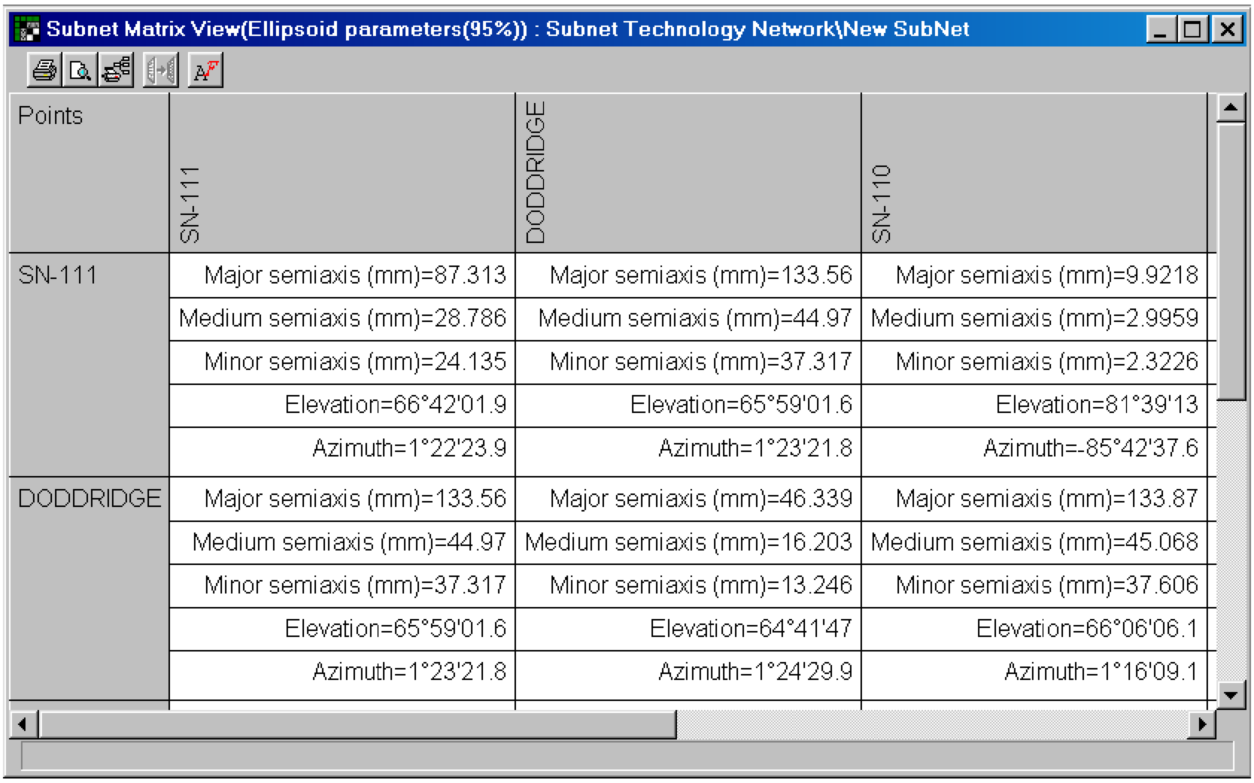
Subnet Matrix View(Confidence circle(95%)(mm)) : Subnet ...

Points	SN-111	DODDRIDGE	SN-110	SO-101	SN-100
SN-111	28.043	43.836	2.2288	4.4151	43.855
DODDRIDGE	43.836	15.808	43.886	43.626	1.2013
SN-110	2.2288	43.886	28.105	4.9321	43.904
SO-101	4.4151	43.626	4.9321	27.893	43.645
SN-100	43.855	1.2013	43.904	43.645	15.835

Figure 5-11

Note that the diagonal values will describe the points' CEP whereas the off-diagonal ones will do with to the accuracies of the vectors. Same holds true for the table shown in Figure 5-12.

- Semi-major/medium/minor axes of 95% (99%) error ellipsoids



Points	SN-111	DODDRIDGE	SN-110
SN-111	Major semiaxis (mm)=87.313	Major semiaxis (mm)=133.56	Major semiaxis (mm)=9.9218
	Medium semiaxis (mm)=28.786	Medium semiaxis (mm)=44.97	Medium semiaxis (mm)=2.9959
	Minor semiaxis (mm)=24.135	Minor semiaxis (mm)=37.317	Minor semiaxis (mm)=2.3226
	Elevation=66°42'01.9	Elevation=65°59'01.6	Elevation=81°39'13
	Azimuth=1°22'23.9	Azimuth=1°23'21.8	Azimuth=-85°42'37.6
DODDRIDGE	Major semiaxis (mm)=133.56	Major semiaxis (mm)=46.339	Major semiaxis (mm)=133.87
	Medium semiaxis (mm)=44.97	Medium semiaxis (mm)=16.203	Medium semiaxis (mm)=45.068
	Minor semiaxis (mm)=37.317	Minor semiaxis (mm)=13.246	Minor semiaxis (mm)=37.606
	Elevation=65°59'01.6	Elevation=64°41'47	Elevation=66°06'06.1
	Azimuth=1°23'21.8	Azimuth=1°24'29.9	Azimuth=1°16'09.1

Figure 5-12

Note that Elevation and Azimuth describe the direction of the ellipsoid's semi-major axis here.

To display such statistics, right click somewhere in the *Subnet Matrix View* window and choose *Options* from the corresponding pop-up menu.

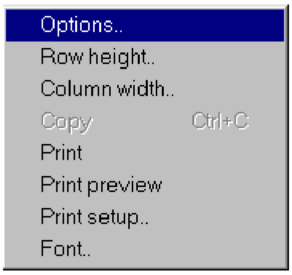


Figure 5-13

The *Matrix View Options* window will be opened.

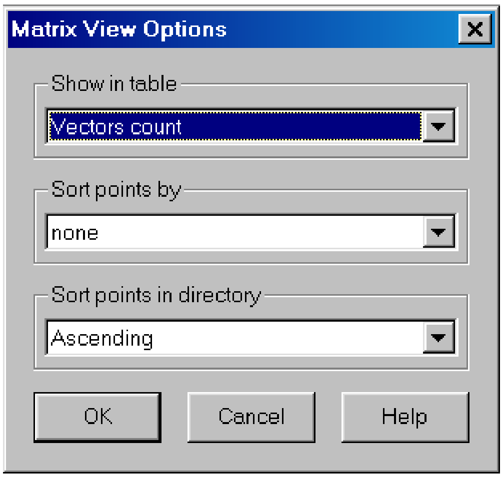


Figure 5-14

Choose the desired statistics from the *Show in table* listbox and press the *OK* button.

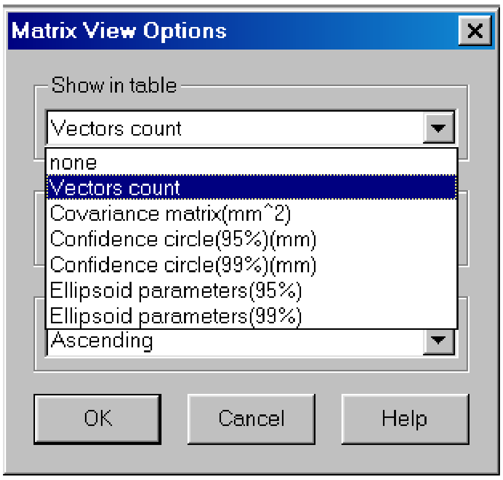


Figure 5-15

The selected statistics will be displayed in the *Subnet Matrix View* window.

5.2.5. Adjustment reports

Adjustment reports will provide the user with detailed information on the adjustment results obtained. Reports are described at great length in [2].

6. *Appendix A. Combining Subnets into One Network*

Assume that the user wants to merge more than one subnet into one larger subnet and then adjust this combined subnet. There are two scenarios for the user to do such a subnet merge (with an eye to further adjustment of the resulting subnet):

1. If all of the individual subnets merged reside in the same network, the subnet merge can be accomplished relatively easily. In this case the user will

- Create a new subnet in the network
- Expand the vectors nodes in the trees of the subnets merged. Further operations are performed identically for each of the subnets merged, one by one.
  - Check the vectors to be added to the new subnet
  - Press down (with the left mouse button) any one of these vectors and drag-and-drop this and the other checked vectors into the new subnet. Once the cursor is placed onto the new subnet node and the LMB is released, the following prompt will appear:

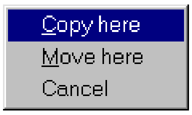


Figure 6-1

  - If the ‘Copy here’ is selected, the checked vectors will be copied to the new subnet. If the ‘Move here’ is selected, the checked vectors will be moved to the new subnet.

2. In case the subnets merged reside in *different networks* of a project or even belong to *different projects*, they can be combined only by using ‘auxiliary’ SNAP points and vectors files. The user will have to export data in one network into SNAP files and then import these files into another network. To export data, right-click on the subnet node, choose *Report…* from the pop-up menu and check *Exports to SNAP* in the *Reports for SubNet* list (see Figure 6-2).

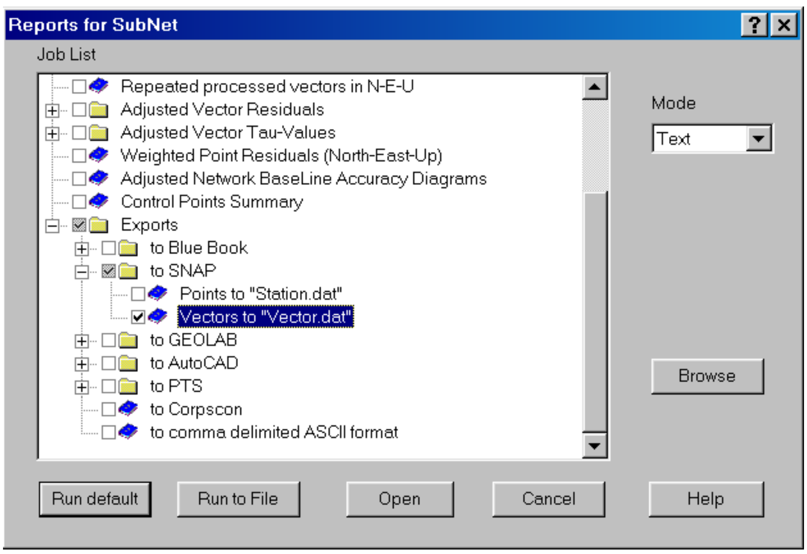


Figure 6-2

Note that data must be exported in *text* mode first for points (*Points to "Station.dat"*) and than for vectors (*Vectors to “Vector.dat”*). Care should be exercised when selecting a file name for each subnet. Please bear in mind that the SNAP *Vector.dat* file format includes information only about vectors, not points, and therefore should be imported into the new network only *after* the corresponding *Station.dat* file is imported there. As a result a solution named "_Snap" will appear in the *Solutions* panel. It will contain all of the vectors that the user wanted to put into the new network.

Further adjustment steps will be straightforward for either scenario.

References

[1] PINNACLE 1.0 Reference Documentation Suite. *Control Data Lists*. **July 2001.**

[2] PINNACLE 1.0 Reference Documentation Suite. *Reports*. **July 2001.**

TOPCON
POSITIONING SYSTEMS

Pinnacle™ Reference Documentation Suite

PROCESSING

User's Manual

This documentation reflects the April 4, 2001 version of Pinnacle 1.0

Last revised July 16, 2001

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1 Introduction

The **Process** module is intended for computing vectors and fans (trajectories) by using raw data measurements stored in **Pinnacle**'s database. The user's final objective is to estimate coordinates for points in a network or along a trajectory. The process module allows fast and accurate computation of the vectors connecting points to other points or points to known control, and the fans connecting points to trajectories .

After a set of static vectors is processed, the corresponding network may be adjusted in the Network Adjustment module to produce final estimates of point coordinates.
After a fan is computed, the resulting trajectory file can be imported into the Event Editor for further post-processing.

Control or "seed" points are used during processing. Control points may be stored in the Control Data Catalog and retrieved by using the Attach Control Points menu. Seed points are entered manually through the Point Properties dialog box.

If no control/seed points are attached, Process will automatically select some to use by criteria based on observation time and accuracy of the estimated coordinates.

Processing coordinates are determined by known coordinates from control or calculated using a vector connecting the point to another with known coordinates. A point with known processing coordinates may be either a control point or a network point whose coordinates have been refined earlier.

A pair of points for which simultaneous measurements are available is associated with a *baseline* (*DBBaseLine*). Computing a baseline results in a Vector (*DBVector)*. Trajectory (*DBTrajectory*) is a set of points representing a rover's positions at consecutive epochs of measurement. Trajectory processing results in a Fan (*DBFan),* which is a set of vectors connecting the base to every point in the trajectory. Vectors and fans are grouped in a *Solution* (*DBSolution*). Note that *Solution* also defines which method of estimating vectors and fans is employed. A *Solution* may contain only <u>one</u> estimate for each vector or fan. Each baseline can be processed more than once, but all of the obtained data will belong to different *Solutions*. Note that the initial p*rocessing coordinates* for all of the vectors and fans in the project will be the same for all relevant *Solutions.*

2 Occupations

The concept of *occupation* plays a very important part in Pinnacle. There are two occupation types in Pinnacle, *static* and *kinematic*. A *static occupation* means collecting raw data measurements at a specific location using a fixed antenna. A *kinematic occupation* means collecting raw data along a trajectory with a moving antenna.
<u>Note</u>. In fact Pinnacle also uses *planned* occupations. These occupations are marked with △. The ***Occupation Planning First*** approach is however not considered in this manual.

3 *Raw Data Sessions* and *Solutions*

3.1 Introduction

Pinnacle, which is an object-oriented software product, is structurally based on ***Raw Data Session***, ***Solution***, ***Subnet***, ***Network*** and several other object types.

When the user imports raw data into a project, Pinnacle will create a new ***Raw Data Session*** and put the imported data into this object. Each ***Raw Data Session*** serves as a “storage repository” for keeping the imported raw data measurements.

After the raw data are loaded into an appropriate ***Raw Data Session***, the user will need to create another object, ***Solution***. This object type serves many important purposes in Pinnacle. For one thing, it is impossible to process a vector or trajectory in Pinnacle without first creating a suitable *Solution* for this vector or trajectory. When creating a new or editing an existing *Solution*, the user will need to specify the following:

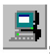
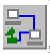
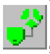
- Which of the vectors/fans existing in the *Solution* will be processed. Note that the user may temporarily disable or permanently delete some or all of the vectors/fans existing in the *Solution.*
- Which of the available raw data measurements will be used to compute the existing vectors/fans. Raw data can be edited in different ways, e.g. raw data can be decimated to every Nth epoch, some satellites can be forbidden for use, etc.
- How the vectors/fans will be computed (the user will need to select the right engine type, processing mode, etc.)

3.2 Create *Raw Data Session*

To create a ***Raw Data Session*** for a network in the current Pinnacle project, the user will take the following steps:

1) Right-click on the network name in the left-hand-most panel of Pinnacle’s main window. A pop-up menu will appear on the screen.

2) Select the ‘***Import…***’ option from the menu. In the ***‘Import – <Network name>’*** window, click on the icon

- , if you want to import raw data from a local disk drive
- , if you want to import data from a remote URL
- , if you want to download raw data from the receiver’s memory directly into the Pinnacle project’s database

Then, follow the instructions shown on the screen.

3.3 Create *Solution*

There are two ways to create a ***Solution***:

- **Drag-and-drop method.** Select the required Raw data session and drag-and-drop it to the Solutions panel.

- Right-click somewhere in the Solutions panel and then select **“New Solution”** from the pop-up menu.

Figure 3-1

4 Solutions

4.1 Introduction

The following is the sequence of steps that the user will normally take when running PROCESS:

1) Create a new or open an existing Pinnacle project.
2) Import raw data files into the project. The imported data will be put into one or more Pinnacle *objects* called ***Raw Data Sessions***. Each ***Raw Data Session*** serves as a “storage repository” for keeping all or some of the imported data.
3) Use the ***Raw Data Sessions*** to create corresponding ***Solutions***. ***Solution*** is another Pinnacle object type that determines how the data from the given ***Raw Data Session(s)*** will be processed.
   Each ***Solution*** will instruct Pinnacle in terms of:
   - Which of the existing vectors/fans will be processed by the engine (the user may disable or delete altogether some of the vectors/fans existing in the ***Solution***)
   - Which of the available raw data measurements will be used to compute these vectors/fans (raw data can be edited in different ways, e.g. raw data can be decimated to every Nth epoch, or some satellites can be forbidden for use, etc.)
   - How the vectors/fans will be computed (the user will select the processing mode and a number of other process settings)

In the Pinnacle project window, ***Raw Data Sessions*** and ***Solutions*** are shown in the left-hand-most and second left-hand-most panels, respectively. For example:

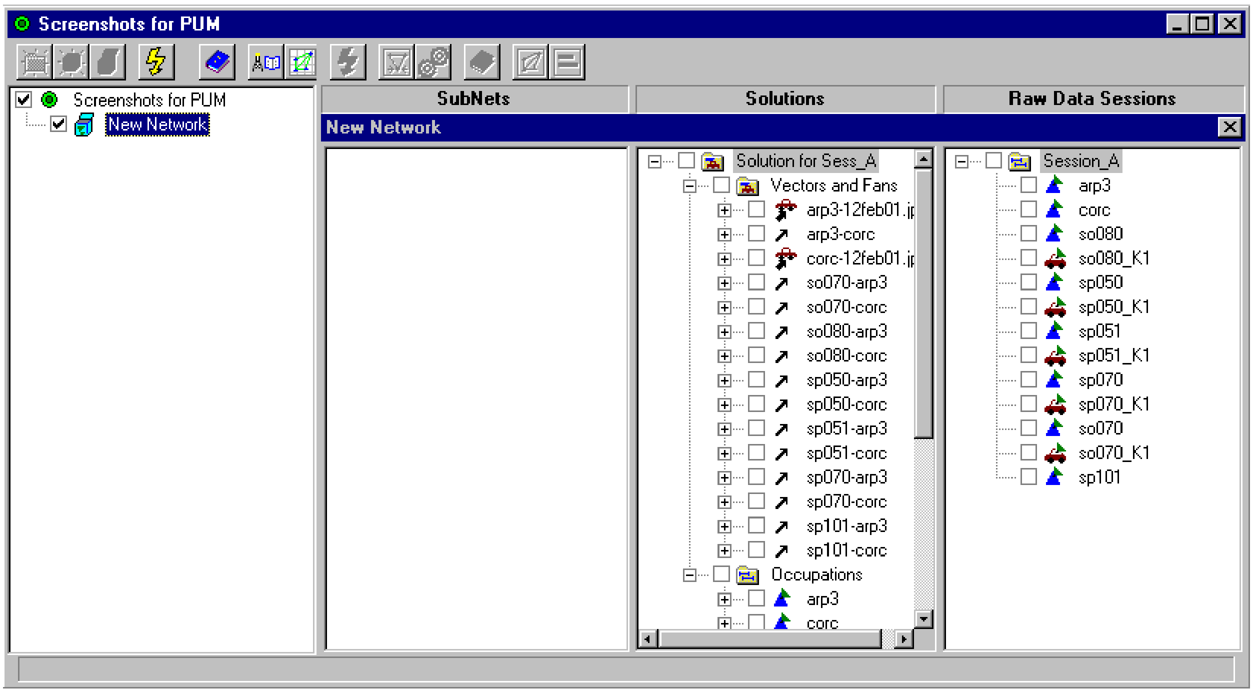


Figure 4-1

Below the reader will find detailed step-by-step instructions on how to create and handle ***Solutions***.

4.2 Create ***Solution***

The user can create an unlimited number of solutions in the *Solutions* panel. There are two ways to create a ***Solution***:

- **Drag-and-drop method.** Select the required Raw data session and drag-and-drop it to the Solutions panel.
- Right-click somewhere in the Solutions panel and then select ***"New Solution"*** from the pop-up menu.

Figure 4-2

If the first way is used, the default Solution name will coincide with the name of the corresponding Raw Data Session. If the second way is used, the default Solution name will be "New Solution", or if a solution with this name already exists, "New Solution(1)", etc.

4.3 Select ***Solution type***

When creating a ***Solution***, the user will be prompted to select a ***Solution type***. Three solution types exist in Pinnacle, ***Static***, ***Stop-and-Go*** and ***Kinematic***.

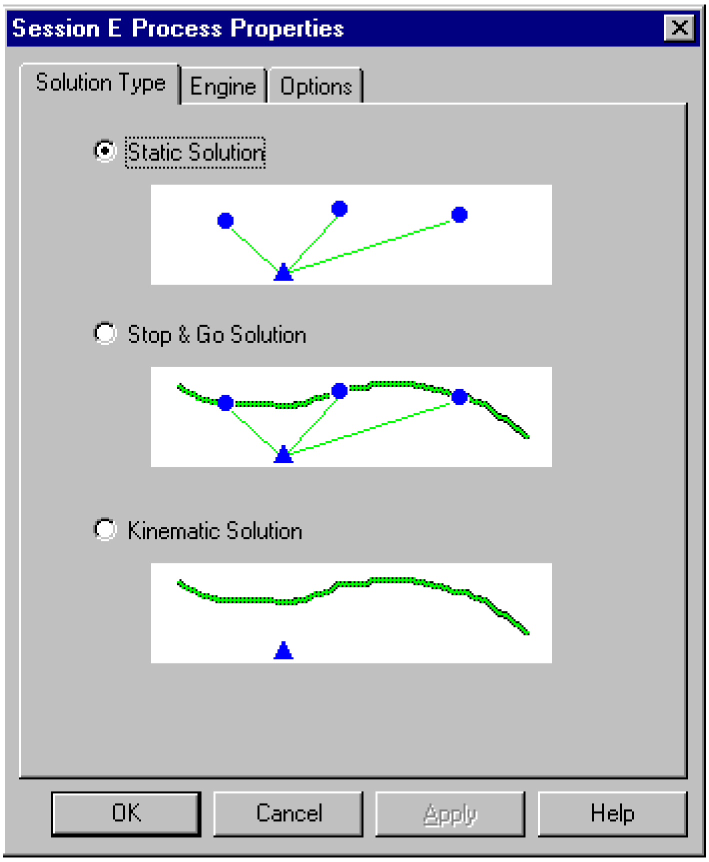


Figure 4-3

Solution type is selected depending on the type of the collected raw data and the particular task that the user needs to accomplish using these data. For example, it would be unreasonable to create a ***Static*** solution if it is known in advance that the raw data loaded into the Solution do not have any overlapping[1] static occupations and thus do not allow any static vectors. (In this case, the list of vectors appearing under 'Vectors' when this node is expanded will be empty).

Note, however, that since it is possible to upload raw data to ***Solutions*** repeatedly, there is nothing unusual or wrong with a Solution whose lists of existing vectors and fans are temporarily empty. The user is supposed to put additional raw data into this Solution during the next steps in order to ultimately make it completely consistent and meaningful[2].

Pinnacle uses different icons to distinguish between ***Solution types*** (see Figure 4-4):

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[1]) overlapping in time

[2]) before running the selected engine

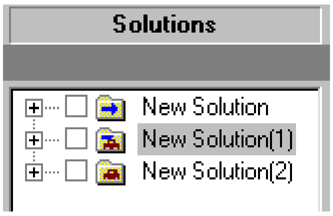

Figure 4-4

The solutions "**New Solution**", "**New Solution(1)**" and "**New Solution(2)**" are of the types *static* , *stop&go* and *kinematic* , respectively.

4.3.1 Static Solutions

When a static Solution is created, only static data (i.e. static occupations) will be taken into account.

To expand the solution tree, the user will need to click on the corresponding node ⊞ .

If the user clicks on the solution name (i.e. root) node, the solution tree will be partially expanded so that the nodes 'Vectors' and 'Occupations' appear on the screen.

To see the lists of the vectors and occupations existing in the solution, the user will need to expand the nodes 'Vectors' and 'Occupations', respectively.

Note 1. To process static solutions, the user can select either ***Static*** or ***Stop-and-go*** engine (see 5.1 and 5.3).

Note 2. Since all kinematic measurements (if any) are discarded when downloading raw data into static solutions, such solutions will not contain any kinematic occupations and fans in them.

4.3.2 Kinematic Solutions

When loading raw data into a kinematic solution, all these data will be included in the solution, irrespective of measurement type. This means that there will be both static and kinematic occupations shown in the corresponding 'Occupations' list.

Note, however, that this solution type deals only with fans, not vectors (thus the name of the corresponding node is 'Fans'). Each fan name comprises two components, the name of a static occupation and the name of a trajectory file, e.g.

In the above example, ***corc*** designates a static occupation and ***12feb01.jps*** stands for a raw data file.

Note. To process kinematic solutions, the user can select either ***Kinematic*** or ***Stop-and-go*** engine (see 5.2 and 5.3).

4.3.3 Stop-and-go Solutions

Stop-and-go can be considered as the most general and versatile solution type used in Pinnacle. It is so because this solution type not only uses both static and kinematic occupations but also allows computation of both static vectors and fans.

If the user expands the 'Occupations' node for a Stop-and-Go Solution, all static and kinematic occupations existing for the solution will be shown in the solution tree.

Since this solution type is intended to handle both vectors and trajectories (fans), the other second-level node in the solution tree will be called 'Vectors and Fans'.

Note. Stop-and-go solutions are always processed with the ***Stop-and-go*** engine (see 5.3).

4.4 Rename a ***Solution***

To rename a ***Solution***, highlight the solution name and then press the **F2** button. Type in a new name for the old one.

Figure 4-5

4.5 Delete a ***Solution***

Highlight and then right-click on the solution name in the Solutions panel. Select 'Delete' from the pull-down menu.

Below (see 7) the user will find a detailed description of functions/operations applicable to ***Solutions*** and their components.

5 Engines

The **Process** module serves as an interface between the Pinnacle database and specialized sub-modules called *engines*. Each engine is tasked to solve the problems within its specific domain.

There are three different engine types available in Pinnacle: ***static***, ***stop-and-go*** and ***kinematic***. Each is designed to process dual frequency, dual system (GPS and GLONASS) measurements.

The user-friendly graphical interface together with many advanced features and state-of-the-art techniques employed in the engines make them powerful yet easy to use tools. For example, the engines incorporate the most advanced techniques for cycle slip detection/correction and fast ambiguity resolution. Each engine is capable of handling up to *several hundred ambiguities at a time.* This makes it possible, among other things, to treat all of the detected carrier phase discontinuities (cycle slips) in a uniform and efficient manner.

5.1 Static Engine

The **Static engine** is intended for computing vectors only. It allows several *static processing* modes based on using different observable combinations and processing techniques.

The **Static engine** is based on a classical least-squares technique.

The vectors are processed one by one, independently. Data processing is adaptive depending on baseline length, total number of measurements, observation time, and other considerations. Vector solutions can be ***fixed***, ***float*** or ***unambiguous*** depending on the selected processing mode and the "quality" of the estimated ambiguity vector[3].

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[3]) Note that this classification is conventional. VLBL solutions will be referred to as unambiguous since triple differenced carrier phase equations are free of biases. L1&L2c solutions will be referred to as *fixed* if and only if the corresponding intermediate L1&L2 solutions are fixed (despite the fact that biases in the final ionosphere-free combinations are intrinsically float)

Float solutions are sometimes referred to as ***partial***. In fixed solutions, which are normally most accurate, all integer biases are fixed. In float (partial) solutions, some integer biases may be fixed while the other are kept as float. Even if there is only one float bias in the estimated ambiguity vector, the corresponding solution will nevertheless be referred to as float (partial).
It is noteworthy that the static engine is equally appropriate for use in both *rapid* and *normal static* scenarios.

5.2 Kinematic Engine

This engine, which too is a least-squares estimator, is intended for processing fans (trajectories) only.

In Pinnacle, each fan will be associated with a pair "***base static occupation*** & ***rover file***" on condition that the raw data measurements for the base occupation and the rover file overlap in time (at least partially).

The rover file associated with a fan must have at least one kinematic occupation. Purely static raw data files therefore cannot serve as "rover files" for Pinnacle's kinematic solutions.

On the other hand, *base static occupations* associated with Pinnacle's fans will always belong to purely static raw data files. Note that such files may have more than one static occupation in them[4].

All static occupations in a fan's rover file will be processed as if they are kinematic. This means that the kinematic engine will produce only trajectory output files ("trajectory reports") omitting any static vector information.

Although the terms "fixed solution" and "float solution" are also applicable to computed fans, there are nuances due to the differences between vectors and fans. We can apply the terms "fixed" and "float" to a computed vector[5], but we do not normally apply "fixed" or "float" to an entire computed fan. For computed fans, the attributes "fixed" and "float" are normally associated with individual trajectory points (or more precisely with separate trajectory segments). Note that in Pinnacle longer trajectories are divided into segments that are then processed one by one. Each segment will then have its own ambiguity vector; and thus different solution types ("fixed", "float") for different trajectory points.

Note1. **Kinematic Engine** requires no initialization at startup time since any trajectory is processed as a whole.
Note2. This engine does not allow ***relative kinematic***.

5.3 Stop-and-go Engine

This is the most versatile and powerful of the three engines that Pinnacle incorporates. The ***Stop-and-go*** engine can be used not only in any *mixed data* scenarios (i.e., when the user needs to compute all static vectors and fans residing in a stop-and-go solution)

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[4]) The field operator may want to record all static raw data measurements collected at several different locations into a single logfile (note that the GRIL provides the "append file" feature). After downloading such a logfile from the receiver, the operator will get *a multiple static occupation JPS file*. Such files are rarely used in practice though.

[5]) assuming the selected processing mode is based on integer ambiguity resolution

but also when the user wants to process purely static or purely kinematic measurements.

The ***Stop-and-go*** engine allows simultaneous calculation of all trajectory points and all vectors associated with the given stop-and-go trajectory unless the total amount of raw data existing for this trajectory is greater than a certain limit. If this limit is exceeded, the engine will implicitly divide the trajectory into smaller segments and will process each data segment separately. Trajectory segmentation is necessary for the engine to store all input and temporary data in the computer's RAM, not in the much slower HD memory. Note that the segment size is normally selected to be large enough to ensure that the sub-optimal processing scheme remains "nearly equivalent" to the optimal processing method.

The user can process fans residing in kinematic solutions with either ***Stop-and-go*** or ***Kinematic*** engine. Potential accuracy and reliability are basically the same for either engine. For vector processing, however, the ***Stop-and-go*** engine may in some cases have considerable advantages over the ***Static*** engine. To illustrate this, consider the following two main scenarios.

- **Scenario#1:** *Vectors, which have been measured in the static survey mode, are loaded into a static solution*

  It this case, it does not make much difference which engine (***Stop-and-go*** or ***Static***) is used to process static vectors since the two engines are nearly equivalent in terms of their capability of computing 'bare' vectors from static solutions.

- **Scenario#2:** *Vectors, which have been measured in the stop-and-go survey mode, are loaded into a stop-and-go solution*

The advantages of ***Stop-and-go*** over ***Static*** will be especially obvious if the static occupations on the rover side are very short. It is common practice today that the static data collection time does not exceed several seconds at the rover in *stop-and-go* mode. If the user loads such stop-and-go measurements into a static solution and then makes an attempt to compute the 'bare' vectors with either ***Stop-and-go*** or ***Static*** engine, the attempt will probably be unsuccessful due to insufficient raw data measurements for the rover end of the baseline. (The engine may not be capable of fixing integer ambiguities and therefore getting sub-centimeter accuracies when static occupations are so short).
On the other hand, if the user puts such stop-and-go measurements into a stop-and-go solution and then runs the ***Stop-and-go*** engine to process the existing vectors, the vector processing will most likely result in good *fixed* vector estimates. This is because the engine will try to resolve the ambiguities for the vectors using not only their own static occupations but *also the adjacent kinematic occupations*. Once the ambiguities are fixed, even a several second long static occupation will be sufficient to obtain a good final vector estimate.
Warning. When processing a vector from a stop-and-go solution with the 'Process Vector' option from the context menu, Pinnacle will use exclusively static occupations existing for the vector, i.e. none of the '*adjacent*' kinematic occupations will be used in this case.

6 Operations on Raw Data Sessions (RDS)

6.1 General structure of a Raw Data Session tree

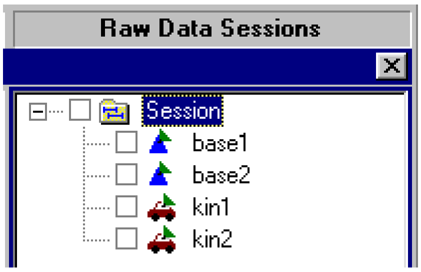


Figure 6-1

To expand a *Session*'s tree, click on the corresponding session node.
Each *Raw Data Session* tree will comprise a finite number of static and/or kinematic occupations.

6.2 Operations on a Raw Data Session

These operations are available via the pop-up menu invoked by right-clicking on the session node.

Figure 6-2

(1) Create a new RDS.
(2) "TO BUFFER" and "FROM BUFFER". These options relate to *session mask* operations. If the user checks some of the sessions in the RDS panel and then selects "TO BUFFER", this information (i.e. session masks) will be stored into the project's buffer. If the user then selects "FROM BUFFER", all the checks will be restored according to the session masks stored in the buffer.
(3) The ***Delete*** option is used to delete sessions.
(4) The ***Report*** option allows the user to view or save to files general information on the session's occupations and the corresponding *occupations vs. receivers* graph.
(5) The ***Occupation view*** option allows the user to view a session's occupations in many different ways, e.g.,
   - "occupation vs. receivers"
   - "occupation vs. points"
   - "occupation (satellite bars) vs. receivers"
   - "occupation (satellite bars) vs. points", etc.

After the '***Occupation view'*** option is selected, an '***Occupations vs. points'*** graph will appear on the screen, for example:

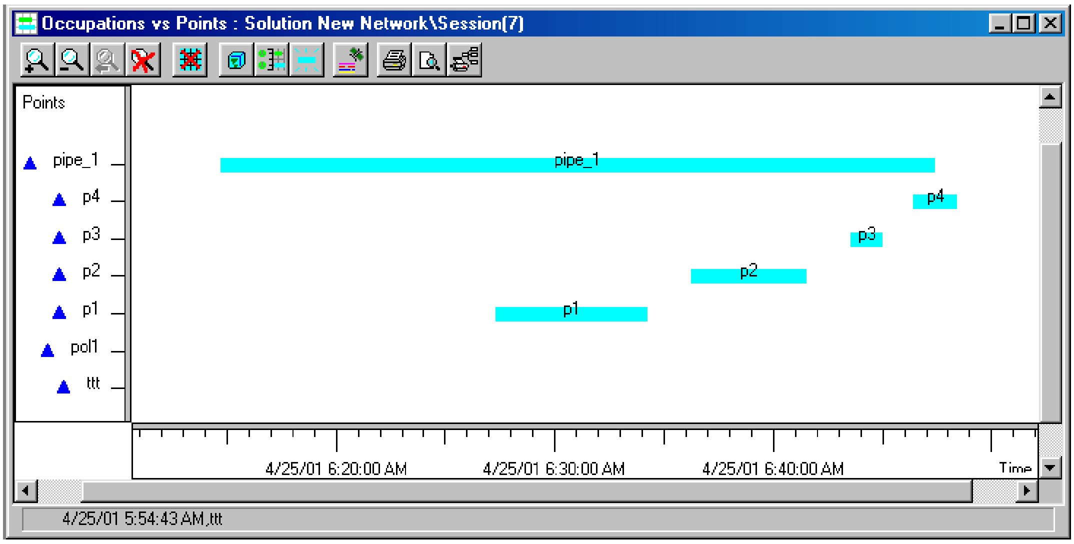


Figure 6-3

If the user right-clicks somewhere in an empty part of the graph, the following menu will pop-up:

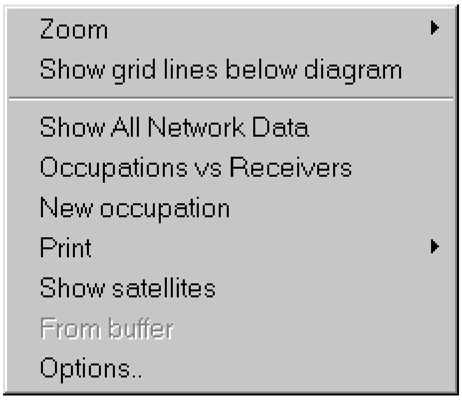


Figure 6-4

If the user then selects the *'Occupations vs Receivers'* option from this menu, the vertical axis of the occupation view graph will show the receivers' serial numbers, for example:

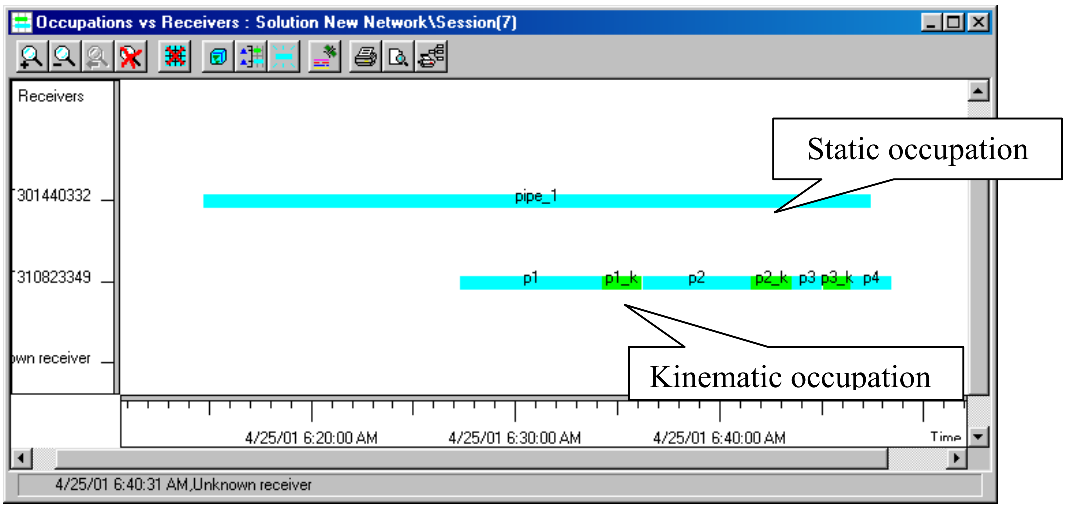


Figure 6-5

Note that static and kinematic occupations are marked in the occupation view graph in light blue and light green, respectively.

If the option “Show satellites” is checked, the *satellite availability* bars will be displayed for each occupation in the session.

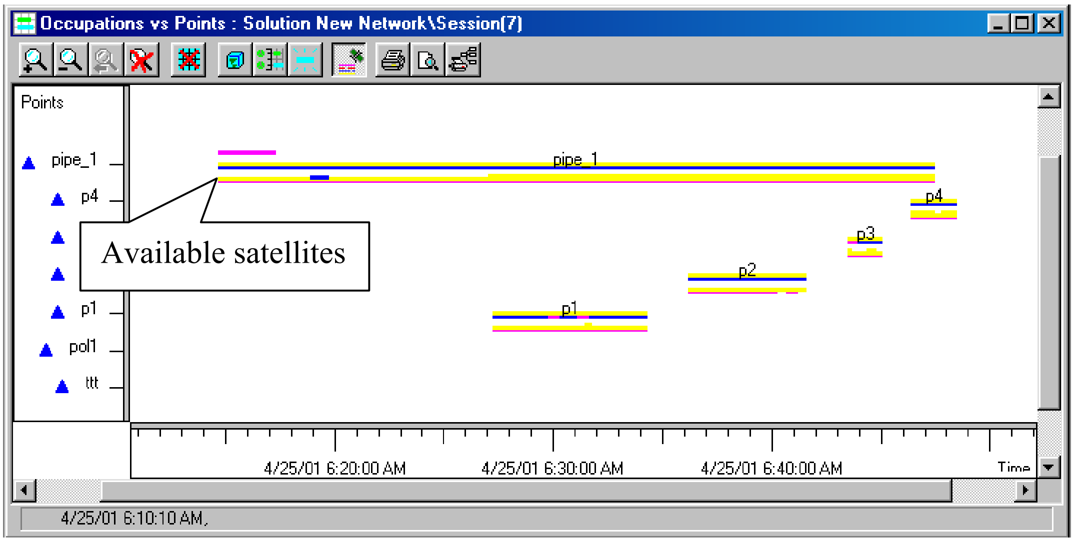


Figure 6-6

Note that the option ‘***Show All Network Data***’ is used to expand the occupation view from the specific session to the entire network that this session corresponds to. More specifically, after the ‘***Show All Network Data***’ option is enabled, the occupation view graphs will show

- Occupations for the entire network
- Points for the entire network
- Receivers for the entire project

Also note that clicking on an occupation bar in the occupation view graph will invoke another pop-up menu thus allowing the user to handle this specific occupation:

Figure 6-7

For detailed information about this menu's options, see 6.4.

6.3 Operations on a group of Raw Data Sessions

If the user checks more than one raw data session and then right-clicks on any of the selected session nodes, the following pull-down menu will appear on the screen:

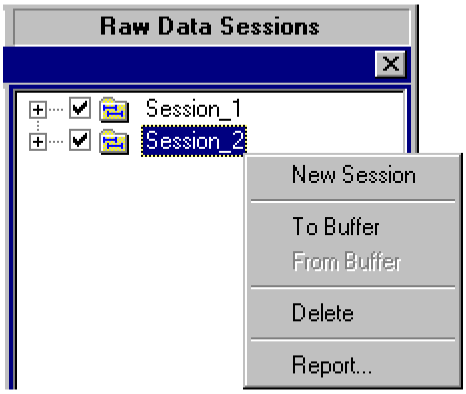


Figure 6-8

The user can:

- Delete all the selected sessions with the '***Delete'*** option
- Display all the *occupation data* on the screen (in either tabular or graphical format) or save it to a file with the '*Report…*' option

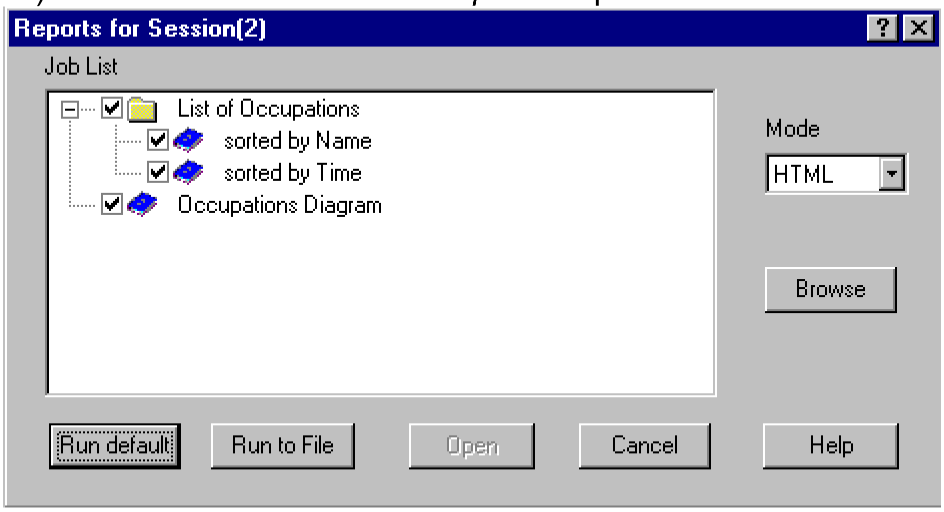


Figure 6-9

- Create a new raw data session
- Save the *checked session* masks into the project database (the user may want to restore these checks later; with the 'From Buffer' option it can be done "at a click of the mouse")

6.4 Operations on an individual Occupation

If the user right-clicks on an occupation, the following menu will drop down:

Menu for a static occupation

Figure 6-10

Menu for a kinematic occupation

Figure 6-11

This menu allows the user to:

- Create a new session
- Save the *checked occupation* masks to the project database so that the user might later easily restore the checks with the "From Buffer" option.
- Delete the checked occupation from the session
- Output the occupation data in the C-, FGI-, or '*epoch view*' format
- Export the occupation data to RINEX
- Divide a multiple day occupation into 24-hour splits
  This operation is carried out automatically (without user intervention). A 24-hour split's name will be generated by appending an underline and the *day of the month* to the original occupation name.
  Example:

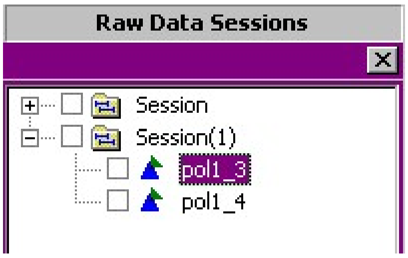


Figure 6-12

- Divide an occupation into two (not necessarily equal) parts. Example:

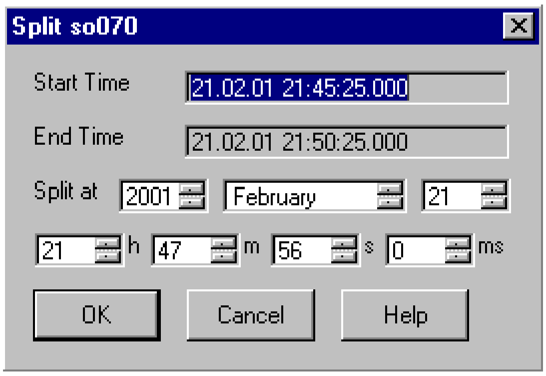


Figure 6-13

- View the occupation's raw data in a graphical (***Raw Data Graph***) or tabular (***Epoch View***) form
- View the properties of the point that the given (static) occupation relates to.The point properties are these:
  - point (site) name
  - preliminary coordinates ("drawn with the mouse")
  - navigational coordinates (computed using code phases from JPS or RINEX files)
  - processing coordinates (refined by means of vector processing)
  - control coordinates (a priori reference data borrowed from a control data list or entered manually)
- Occupation properties
  - Occupation name
  - Occupation type (static or kinematic)
  - Point name (enabled for static occupations only)
  - Antenna information
  - Receiver information
  - Session that the occupation belongs to
  - Source file's pathname
  - Observation time
  - Coordinates

Note1. The 'Merge' option is disabled for individual occupations because this operation is not unary. In Pinnacle, this operation is binary (see 6.5).

Note2. ***'Suspect occupations'***.

If a static occupation is marked with the red triangle icon ▲ (such occupations are referred to as 'suspect occupations'), it means that either

- its *rms position error* is greater than 100 meters, or
- this occupation does not belong to the specified point, or
- this occupation includes only one epoch (averaging out the navigational coordinates is impossible).

In the first case the error message

will appear in the import window when importing raw data including such an occupation.

If a suspect static occupation is encountered in the project, the user should take the following steps:

(1) Make sure that the occupation contains more than one epoch.

(2) Make sure that this occupation is not *kinematic*. The user may want to examine the *xdot*, *ydot*, *zdot* plots for this occupation with the *Raw Data Graph* utility. Zero velocity will indicate that the occupation is indeed static.
(3) Verify the suspect occupation's coordinates. If these coordinates are essentially different from the coordinates of the other occupations corresponding to the same point, the user must change the site name for the suspect occupation (use either one of the existing file names or a new site name).

6.5 Operations on a group of Occupations

<u>*Two occupations are selected*</u>

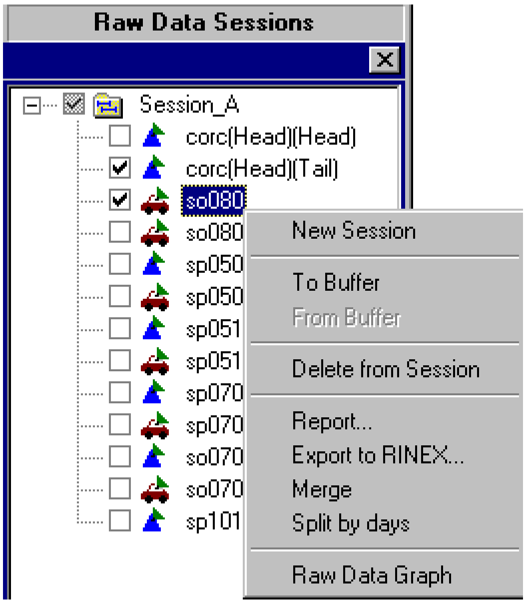


Figure 6-14

<u>*More than two occupations are selected*</u>

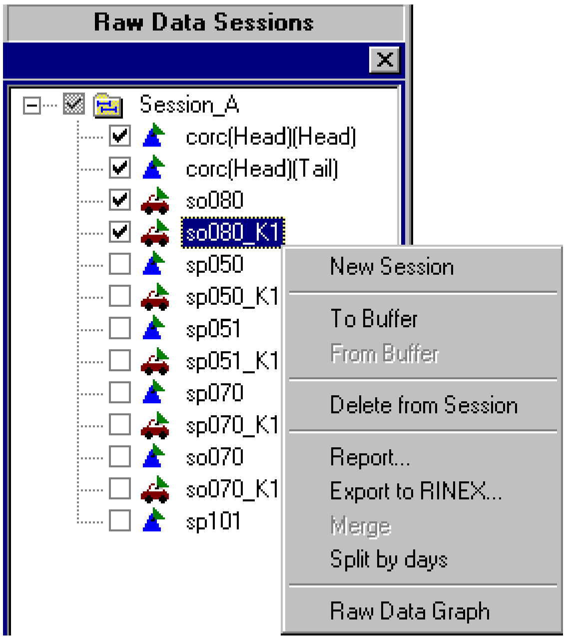


Figure 6-15

In this section we only need to explain the 'Merge' option. All the other options that exist for a group of occupations are also applicable to individual occupations and therefore have already been described in 6.4.

The 'Merge' operation is governed by the following rules:
1) The 'Merge' operation is *binary* in Pinnacle, i.e. only two occupations can be merged at a time.
2) Two static occupations cannot be merged if they correspond to different points.
3) A static occupation can be combined with a kinematic one only if they both correspond to the same *Stop-and-go* file. The resulting occupation will be kinematic.
4) Two kinematic occupations can be merged only if they belong to the same *Stop-and-go* file.
5) Occupations with different recording intervals (a.k.a. "epoch intervals") cannot be merged.
6) Occupations with different antenna parameters and/or serial numbers cannot be merged.
7) Occupations where different antenna types were used cannot be merged.
8) Occupations where different receiver models were used cannot be merged.
9) Occupations cannot be merged if one of them contains single-frequency data and the other dual-frequency data.
10) Planned, deleted and obsolete occupations cannot be merged.

7 Operations on Solutions and their Components

7.1 Operations on an individual Solution

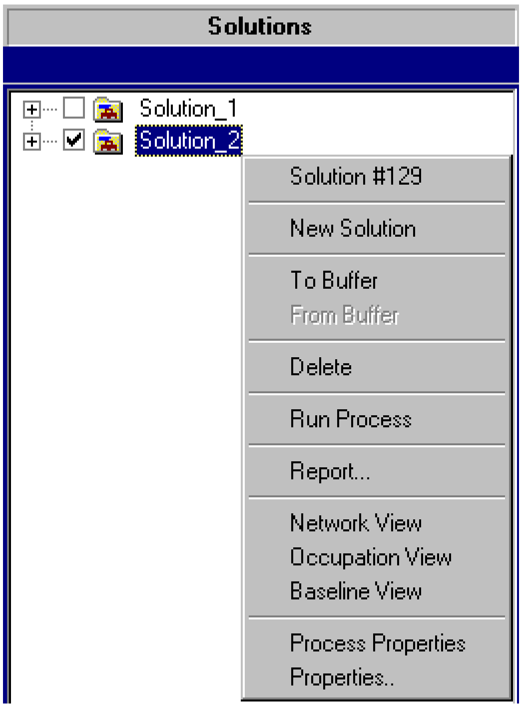


Figure 7-1

7.1.1 New Solution

This option is used to create a new (empty) solution.

7.1.2 To Buffer / From Buffer

The '*To buffer*' option allows the user the save the *checked solution* masks to the buffer. The user can later restore these checks back "at a click of the mouse" (by selecting the '*From buffer*' option).

7.1.3 Delete

This option is used to delete the solution from the project.
If '**Delete'** is pressed, the following prompt will appear:

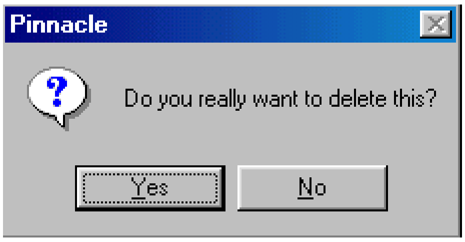


Figure 7-2

Selecting 'Yes' will result in permanent deletion of the *Solution*.

7.1.4 Run Process

Press ***Run Process*** to start the processing of vectors and/or fans corresponding to the given *Solution*.

7.1.5 Report…

This option allows the user to output vector/trajectory processing results in different graphical and text formats ().

Reports will be described at great depth in [1].

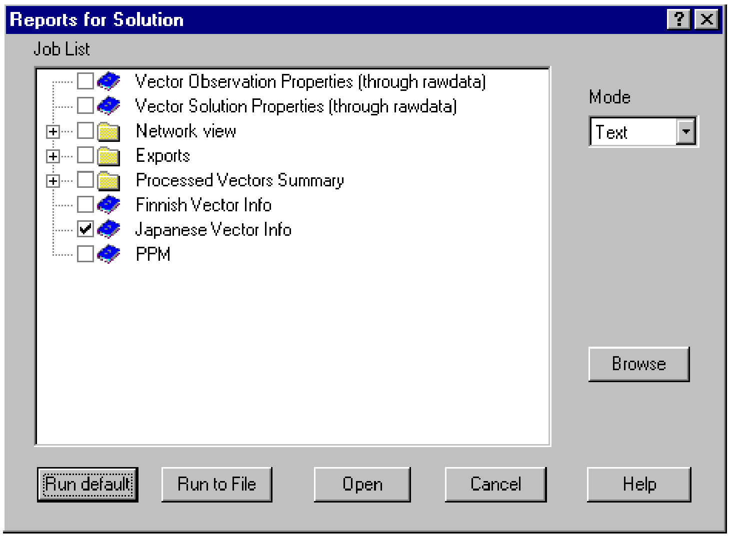


Figure 7-3

7.1.6 Network View

This option allows the user to view the *Solution*'s vectors and fans (unprocessed or processed, enabled or disabled) in the selected coordinate system/datum/projection.

The graphical notation used for vectors and fans in the ***Network view*** window is as follows:

Vectors:

	processed	unprocessed
Enabled	***dark green***	***black***
Disabled	***light green***	***gray***

Note: Processed vectors whose rms errors exceed the threshold value "1 meter + 10 ppm" will be marked ***red***.

Fans:

processed	unprocessed
dark green	***black***

Example.

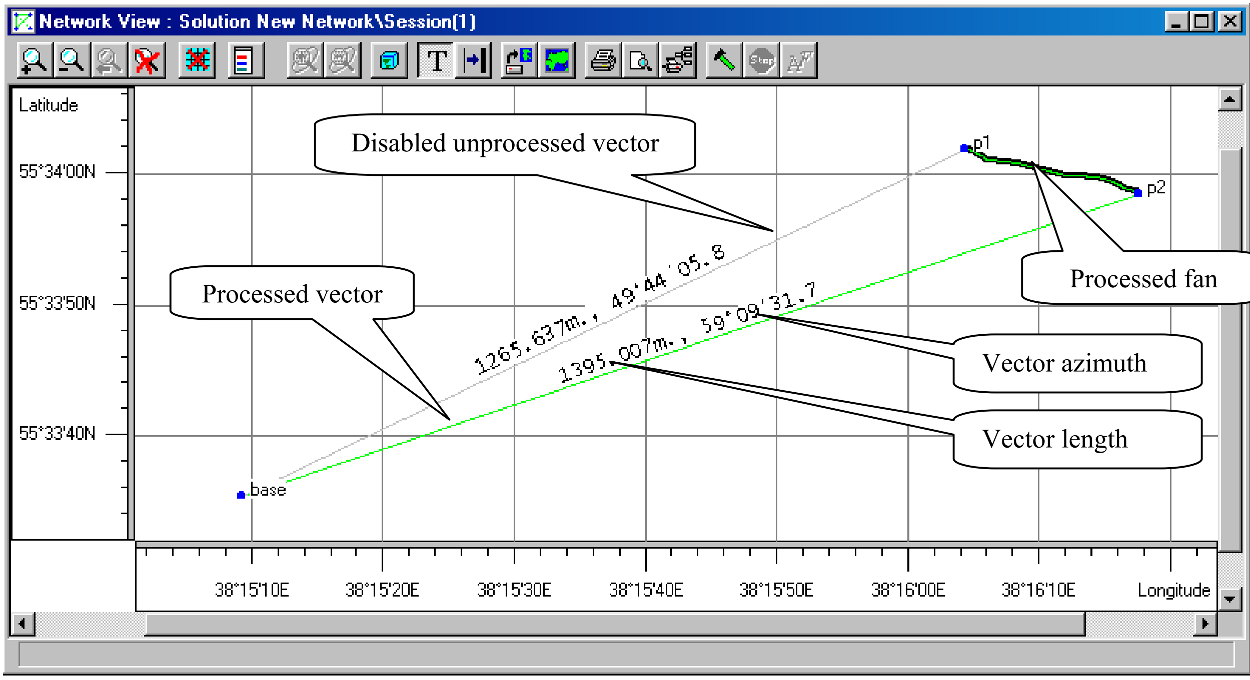


Figure 7-4

7.1.7 Occupation View

Occupation View can be invoked for a specific solution exactly as for a specific raw data session (see 6.2).

7.1.8 Baseline View

Pinnacle allows different ways to enable/disable vectors in a *Solution*. The option ***Baseline View*** also serves this purpose.

After the option is selected, the following *Baseline View* window will appear on the screen (assuming the default settings):

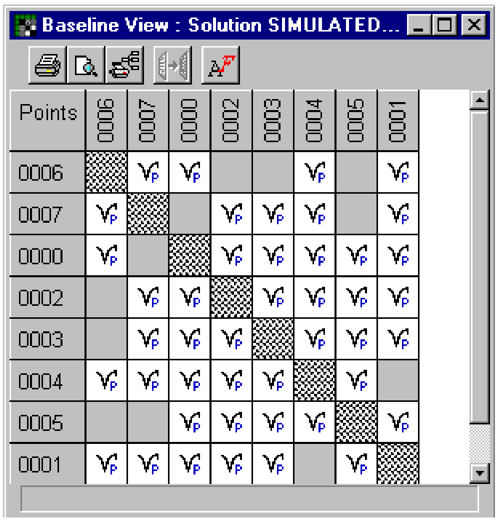


Figure 7-5

The checks, which are located symmetrically with respect to the main diagonal, will designate the baselines “point1-point2” that are enabled for processing. To disable a

particular baseline, double click on either of the cells corresponding to this baseline. After this both the cells will become deselected (unchecked).
Conversely, to enable this baseline back, double click on either of its cells.

With the ***Baseline View*** option, the user can also view baseline lengths (in meters). Moreover, the user may want to use the lower part of the baseline matrix to enable/disable vectors and the upper part to view the baseline lengths (see the example below).

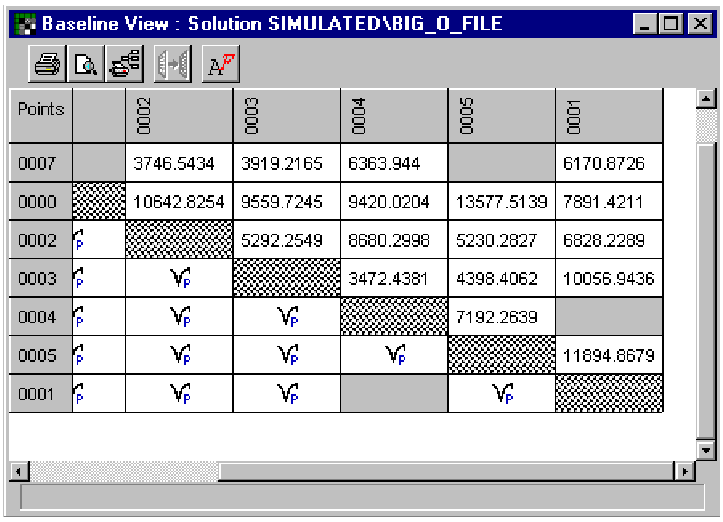


Figure 7-6

7.1.9 Process Properties

After the user selects the ***Process Properties*** option, the following two-panel dialog window will appear:

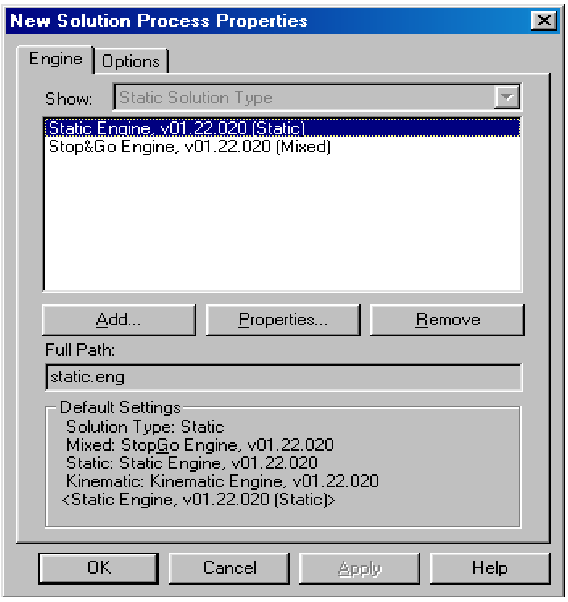


Figure 7-7

In the ***Engine*** panel, the user must specify which particular "engine" will be used to process the given *Solution*. The user can

- o Choose a pre-defined engine from the list shown at the top of the panel
- o Remove an unnecessary engine from the list by using the button '*Remove*'
- o Select an engine other than the pre-defined ones by using the '*Add…'* button.

The list of pre-defined engines will depend on the selected Solution type (see 5 for more details). Note that static solutions can be processed with either ***Static*** or ***Stop&Go*** engine, kinematic solutions with either ***Kinematic*** or ***Stop&Go*** engine, and stop-and-go solutions with ***Stop&Go*** engine only.

The ***Properties…*** button plays a very important part in the Pinnacle Process module. Its functions will be discussed in detail in 8.

The other panel, ***Options***, allows the user to specify the way in which intermediate processing data will be displayed.

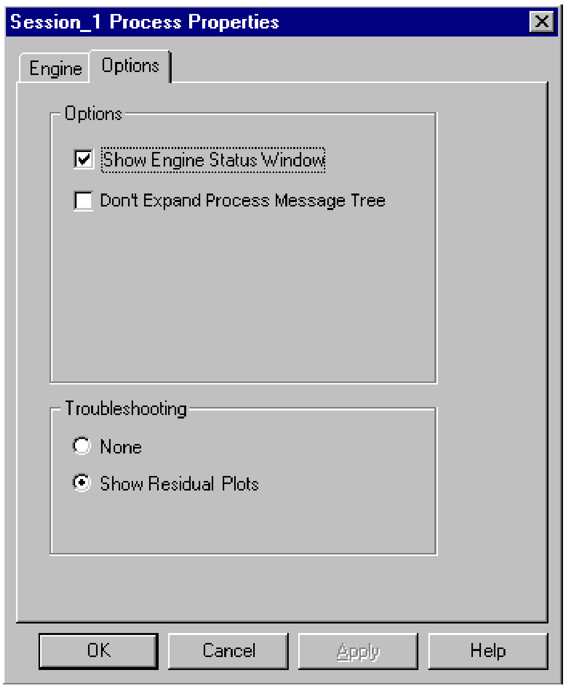


Figure 7-8

If the checkbox "Show Engine Status Window" is selected (as shown in Figure 7-8), the engine status dialog box will be displayed while the engine processing vectors and/or fans (see Figure 7-9):

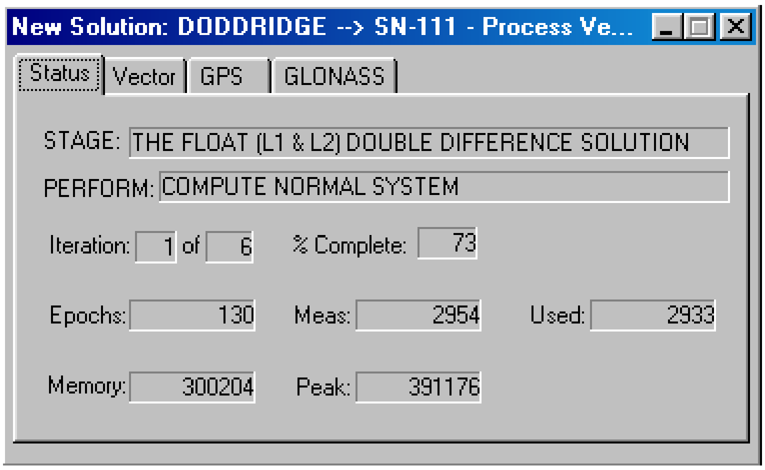


Figure 7-9

Note that when processing a vector or fan from a stop-and-go solution, its engine status window will have only three panels (the 'Vector' panel will be unavailable)

STAGE indicates the current processing stage (*single differenced solution*, *float double differenced solution*, *ambiguity resolution*, *fixed double differenced solution*, *unambiguous solution, triple differenced solution)*.
PERFORM indicates the current computational operation (*data loading*, *computing normal system*, *computing residuals*, *estimating variance-covariance matrix*, etc.).
Iteration: shows the current iteration / total number of iterations,
% Complete: indicates the percentage of data already processed at the current stage,
Epochs: indicates the amount of already processed epochs
Meas: indicates the total number of available DD measurements. It meets the equation ***Meas*** = ***Epochs*** * ***Ndd*** * ***K***, where ***Ndd*** stands for the number of DD observables per epoch, ***Epochs*** stands for the total number of epochs, ***K*** stands for the total number of channels (C/A, L1, L2) for which DD observables are available,
Used: means the total number of DD observables left after filtering out outliers.
Memory: means dynamically allocated memory in current use (in bytes)
Peak: means the peak amount of dynamically allocated memory that has been used at the current stage (in bytes).

In the ***Vector*** panel the user will find the current estimates of the vector's coordinates in the WGS84, ENU and 'Azim-Elev_Dist' systems as well as the 'deltas' indicating whether or not the vector computation process converges. Normally, vector computation precision will improve from iteration to iteration.

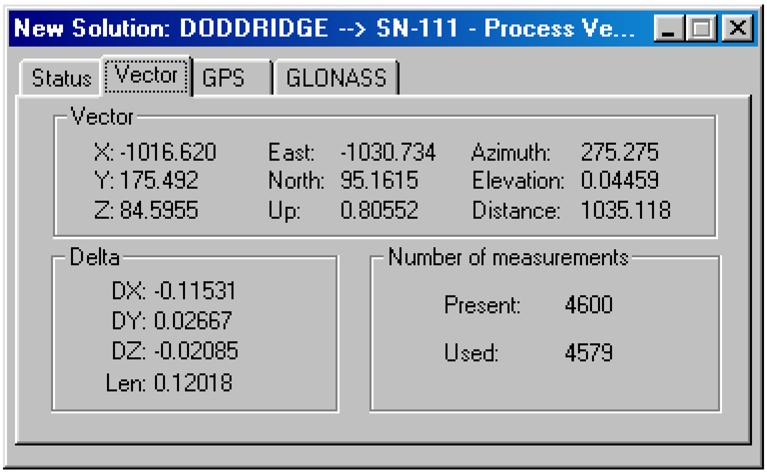


Figure 7-10

From the ***GPS*** (***GLONASS***) panel the user will learn how many observables and of what type are used in vector computation. Besides, this panel will show the mean root-squared residual errors for both carrier and code phase observables (if both observable types are enabled).

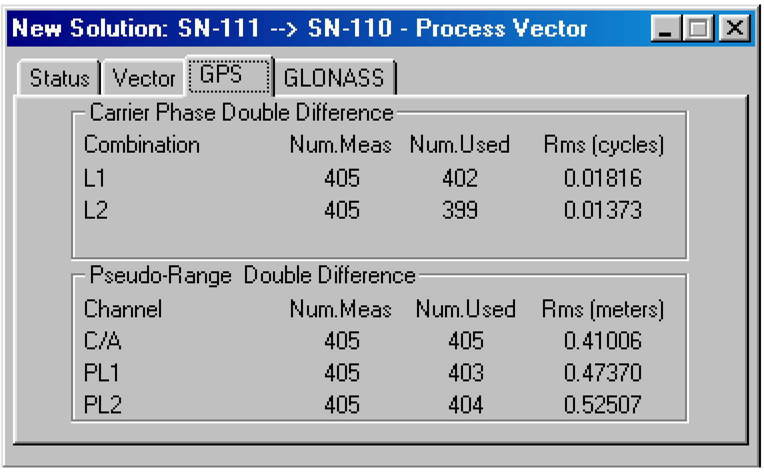


Figure 7-11

7.1.10 Solution Properties

The ***Solution Properties*** dialog window comprises two panels, ***General*** and ***Make dependencies***.

The ***General*** panel shows the following data:

- Solution name
- Number of vectors in the Solution
- Number of fans in the Solution
- Number of disabled vectors
- Number of disabled fans
- Number of occupations in the Solution
- Number of disabled occupations

The other panel lists all the raw data sessions that are associated with the given Solution (i.e. the sessions whose occupations are used in the Solution).

7.2 Operations on a group of Solutions

There are only a few operations applicable to a group of *Solutions* (see the screenshot below).
The '*Delete'* option allows deletion of several checked Solutions at a time.
Similarly, the user can start the processing of several checked Solutions (one by one) by clicking on the '*Run'* option.
The '*Report*' option allows the user to output data for multiple checked *Solutions* simultaneously. Note that the list of reports available for a group of *Solutions* is exactly the same as for a single *Solution* (see Figure 7-3 in 7.1.5).

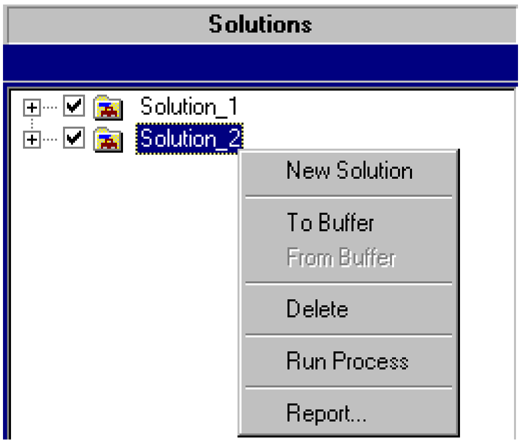


Figure 7-12

7.3 Operations on an individual Vector

Highlight the desired vector and then right-click on it. The following menu will pop-up on the screen:

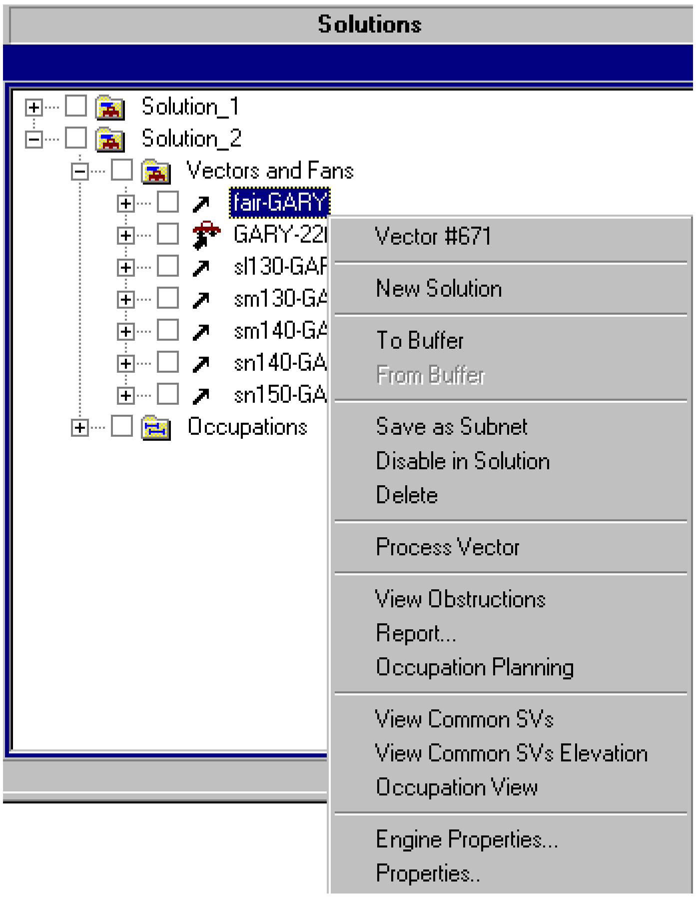


Figure 7-13

7.3.1 New Solution

This option allows the user to create a new (empty) Solution.

7.3.2 To Buffer/ From Buffer

The '*To buffer*' option allows the user the save the *checked vector* masks to the buffer. The user can later restore these checks by clicking on the '*From buffer*' option.

7.3.3 Save as Subnet

With the ***Save as SubNet*** option, the user can create a new *Subnet* and put some or all of the *Solution*'s vectors into this *Subnet*.
This option is especially useful if the user wants to put into a created *Subnet* only <u>some</u> of the vectors that the *Solution* contains (otherwise it will be easier to drag and drop the entire *Solution* into the *Subnet* panel).

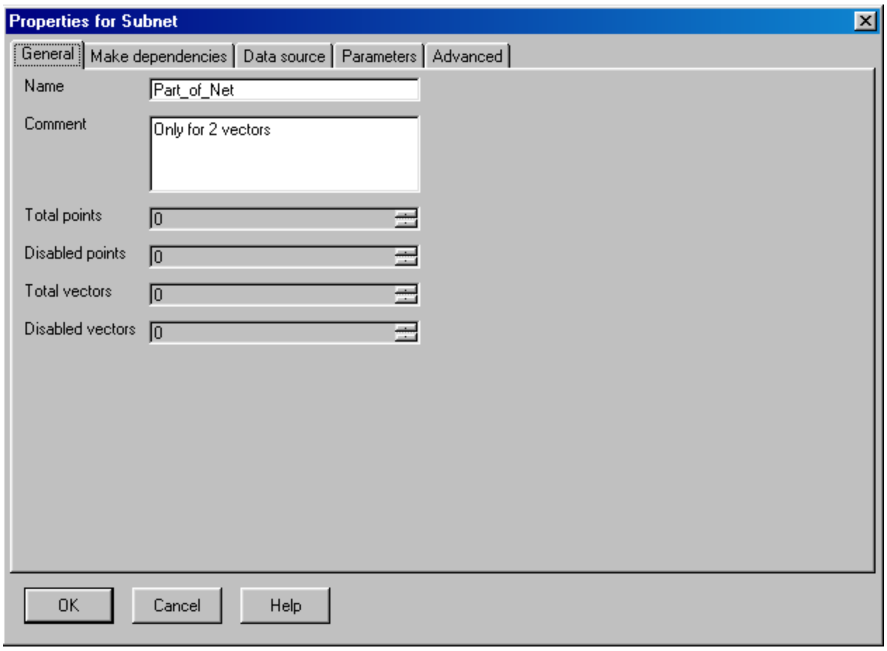


Figure 7-14

In this way the user can not only create a new Subnet but also specify adjustment parameters for it. To do this, the user must open the panels ***Parameters*** and ***Advanced*** and make the necessary settings there. After the adjustment parameters are entered and the user presses the 'OK' button, a new Subnet node will appear in the Subnets panel.

7.3.4 Disable/Enable in Solution

After the option ***Disable in Solution*** is applied to a vector, its icon will change to
- , if the vector has <u>*not*</u> been processed,
- , if the vector has been processed,
- , if the vector has been processed but its rms error exceeds the *1 meter + 10 ppm* threshold value.
Conversely, after applying the '*Enable in Solution*' function to a disabled vector, the 'light' color will change back to 'dark'.

7.3.5 Delete

After the user selects ***Delete***, the following prompt will pop-up on the screen:

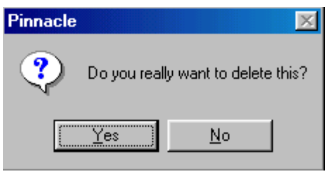


Figure 7-15

Pressing the ***Yes*** button will result in permanent deletion of the vector from the ***Solution***.

7.3.6 Process Vector

The option ***Process Vector*** is equivalent to ***Run Process*** yet applies only to vectors.

7.3.7 View Obstruction

The option ***View Obstruction*** is used to view the obstructions specified for the vector[6] at the *project planning* stage.

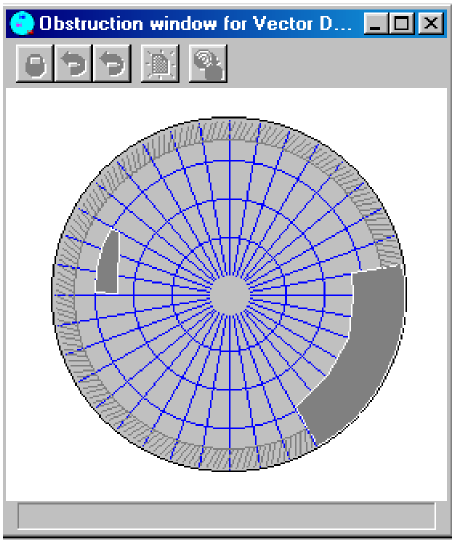


Figure 7-16

7.3.8 Report…

Vector processing results can be output in different *report formats* in Pinnacle:

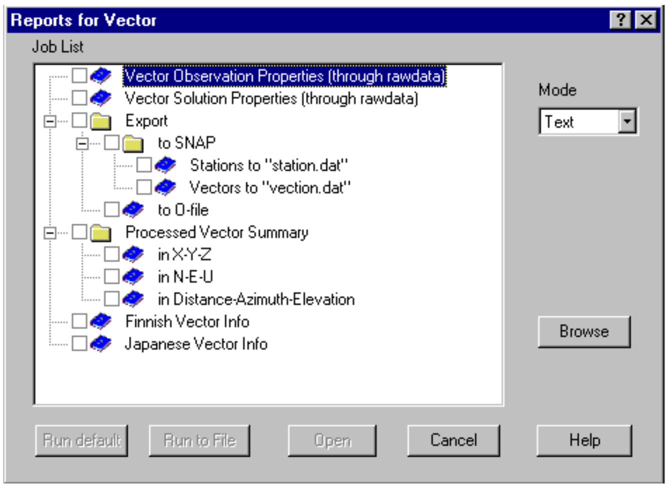


Figure 7-17

For detailed information on vector reports, refer to [1].

---

6) More precisely, obstructions are specified for vectors' end-points in Pinnacle

7.3.9 Occupation Planning

The option ***Occupation Planning*** allows the user to plan a new occupation for an existing vector. For detailed information about this feature, refer to the documentation on the *Pinnacle Mission Planning* software.

7.3.10 View Common SVs

The option ***View Common SVs*** allows the user to view

(1) The *common measurement* interval for the given vector

(2) How many GPS and GLONASS satellites will be available for vector processing if the elevation angle mask is set to the value specified in the '*Mode'* panel of the '*Engine Properties*' dialog window.

Note that the blue and the red lines designate GPS and GLONASS satellites respectively.

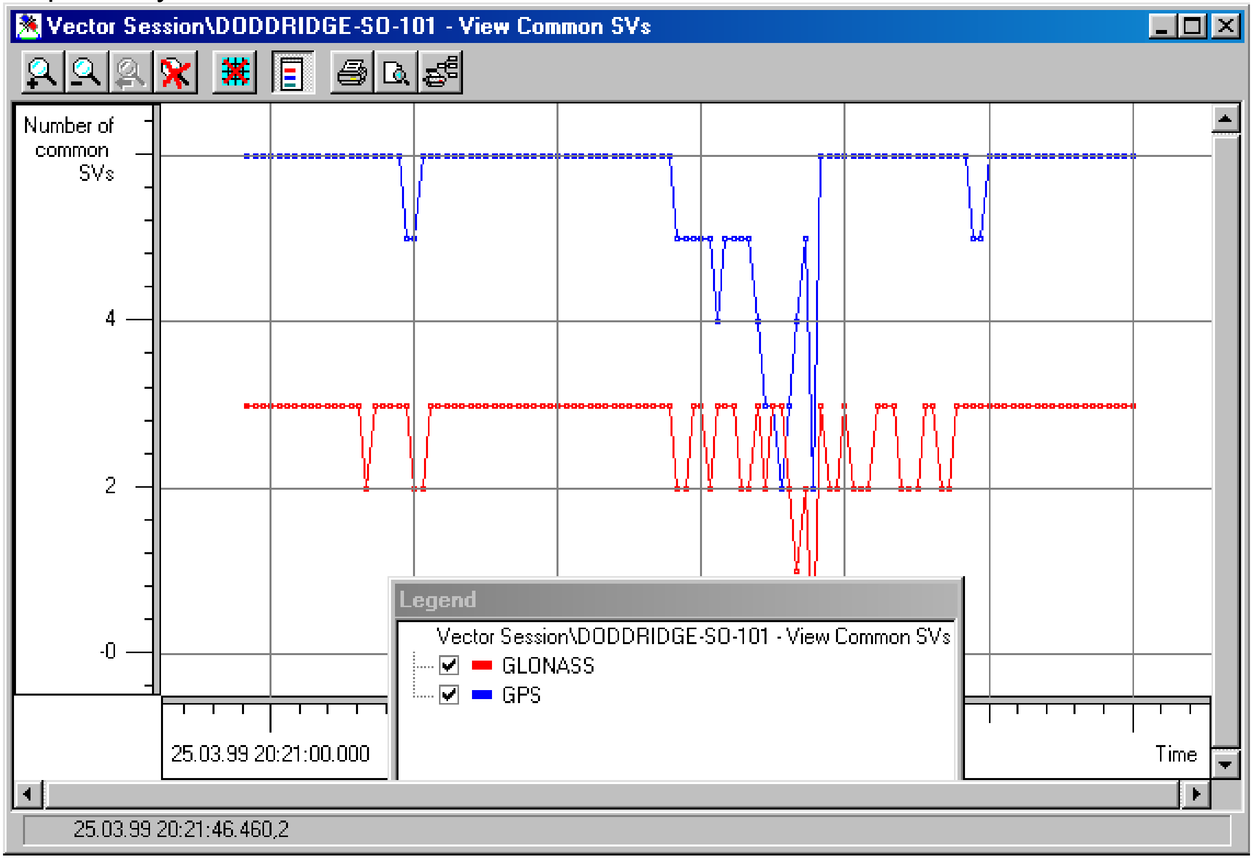


Figure 7-18

7.3.11 View Common SVs Elevation

The option ***View Common SVs Elevation*** allows the user to view the elevation angles of the *common* GPS and GLONASS satellites whose measurements can be used by Pinnacle in vector computation.

The red dotted line (see Figure 7-19) corresponds to the elevation angle mask specified in the '*Mode'* panel of the '*Engine Properties*' dialog window.

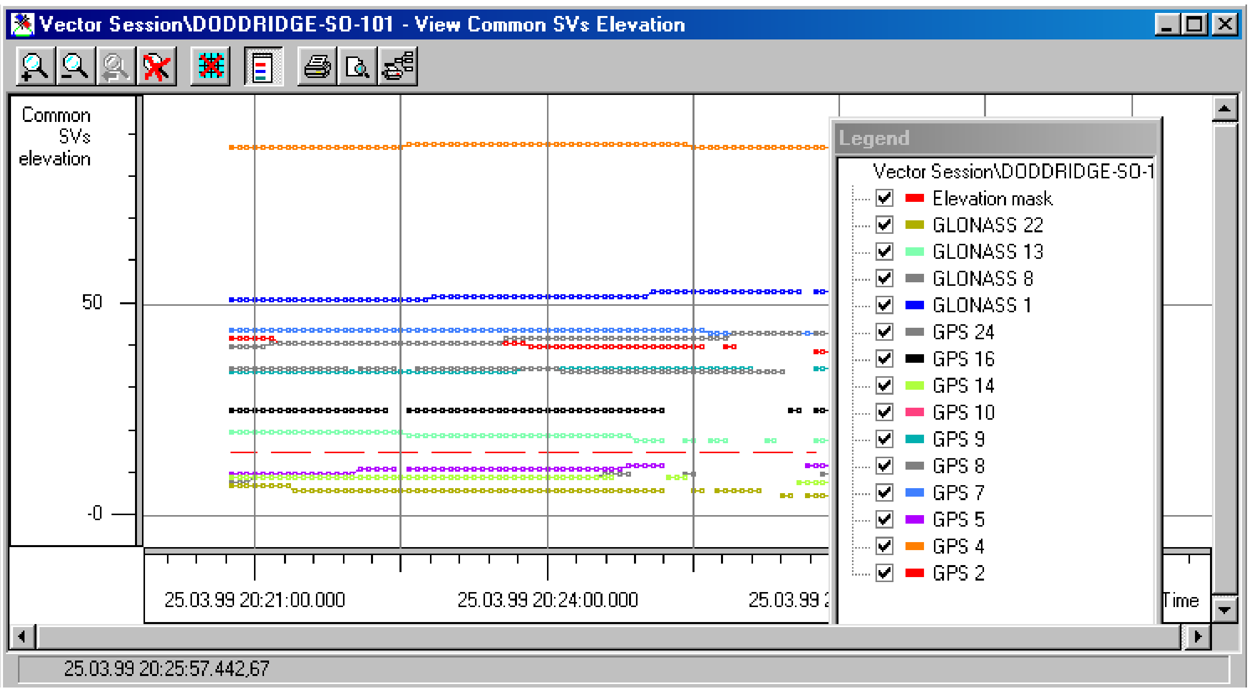


Figure 7-19

7.3.12 Occupation View

The option ***Occupation View*** allows the user to view occupations related to the given vector.

7.3.13 Engine Properties

The option ***Engine Properties*** allows the user to set up the engine parameters for a specific vector. The corresponding five-panel dialog window will be described in detail in 8.

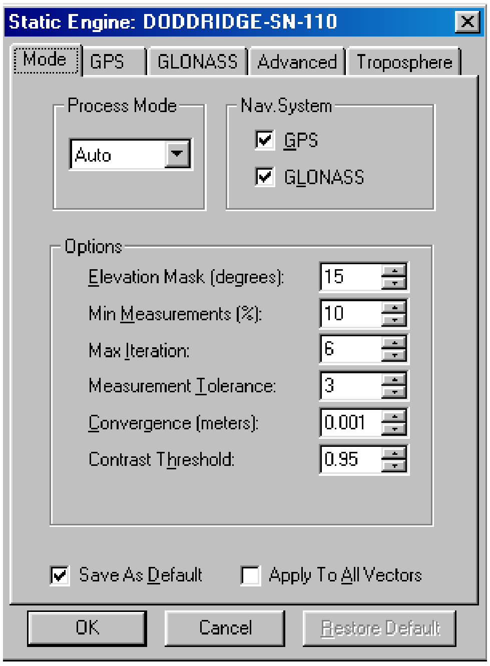


Figure 7-20

By using the checkboxes ***Save As Default*** and ***Apply To All Vectors***, the user can expand the scope of the *Engine Properties* setup thus making it effective not only for the particular vector but also for other vectors existing in the given Solution.
The following table shows how the scope will depend on the ***Save As Default*** and ***Apply To All Vectors*** checkmarks:

Table 1

	Save As Default	***Apply To All Vectors***	**Validity scope**
1	OFF	OFF	Effective for the selected vector only
2	OFF	ON	Effective for all vectors in the ***Solution***
3	ON	OFF	Effective for all vectors that do not have *specific* engine property settings Also, this set-up will apply to all vectors that may appear in the ***Solution*** later.
4	ON	ON	Effective for all vectors in the ***Solution***

7.3.14 Vector Result

The option ***Vector Result*** is used to view the vector processing results. The corresponding six-panel dialog window is described in detail below.

7.3.14.1 X,Y,Z

The ***X,Y,Z*** panel will show the vector in a cartesian coordinate system. This Cartesian system will coincide with the ECEF system used in WGS84 (even if the vector has been computed using *only* GLONASS data).

Vector components are given in meters. Also, this panel shows the rms error for each individual component ("Rms X", "Rms Y", "Rms Z"), the square root of the trace of the variance-covariance matrix ("Rms total") and the correlation factors "X-Y", "X-Z" and "Y-Z".

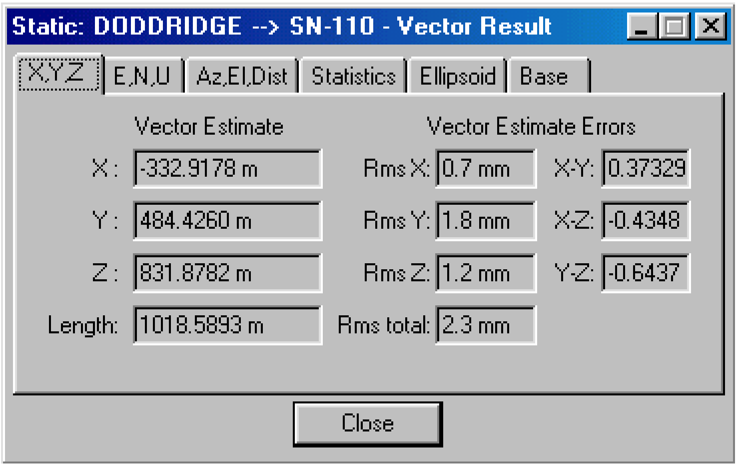


Figure 7-21

7.3.14.2 E,N,U

The ***E,N,U*** panel will show the computed vector in the local coordinate system (*easting-northing-up*).
Vector components are given in meters. Also, this panel shows the rms error for each individual component ("Rms E", "Rms N", "Rms U"), the rms horizontal position error ("Rms H") and the correlation factors "E-N", "E-U" and "N-U".

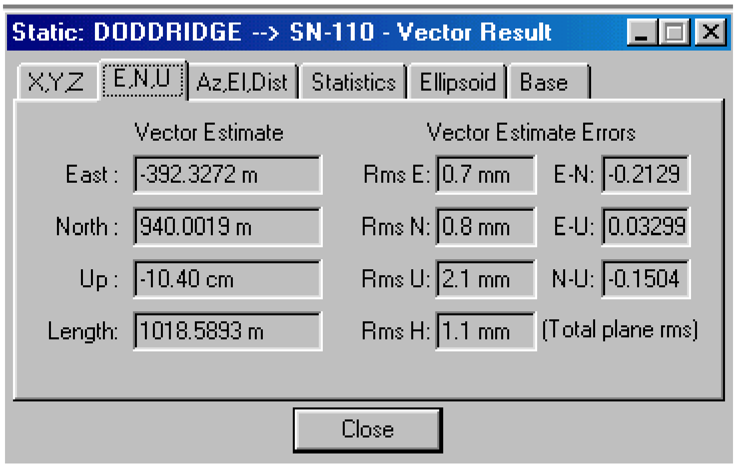


Figure 7-22

7.3.14.3 Az,EL,Dist

The ***Az,EL,Dist*** panel will show the computed vector in the ***azimuth-elevation-distance*** coordinate system.
Note that the rms azimuth and elevation errors are given in both angular (arcseconds) and linear (millimeters) units.

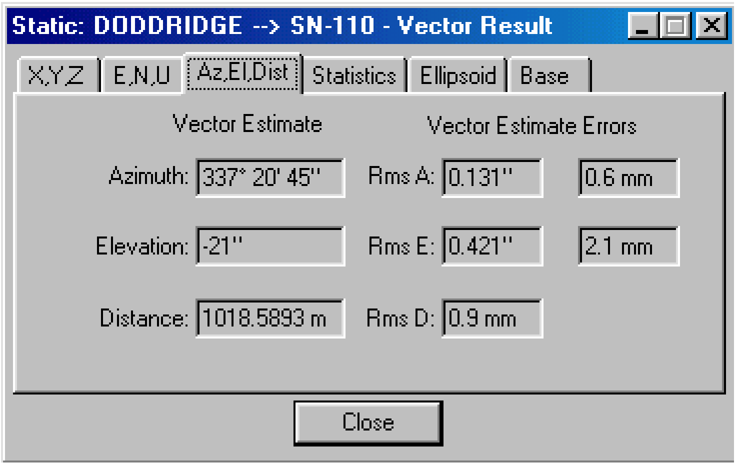


Figure 7-23

7.3.14.4 Statistics

The panel ***Statistics*** will show the following information:
Num Meas: total number of measurements available for the vector
Num Used: number of measurements used in vector computation after removing outliers,
Num Amg: total number of ambiguities
Num Fixed: number of fixed ambiguities
RMS Resid: rms residual error (in millimeters),

Ratio: contrast ratio (in percentage) obtained for the fixed part of the ambiguity vector

The ***Flags*** parameters will designate:

1) Solution type (static, kinematic or stop-and-go),
2) Observable type (single, double or triple differences)
3) Ambuguity vector type (float, partial, fixed)
4) Process mode (L1only, L2only, L1&L2, etc.)

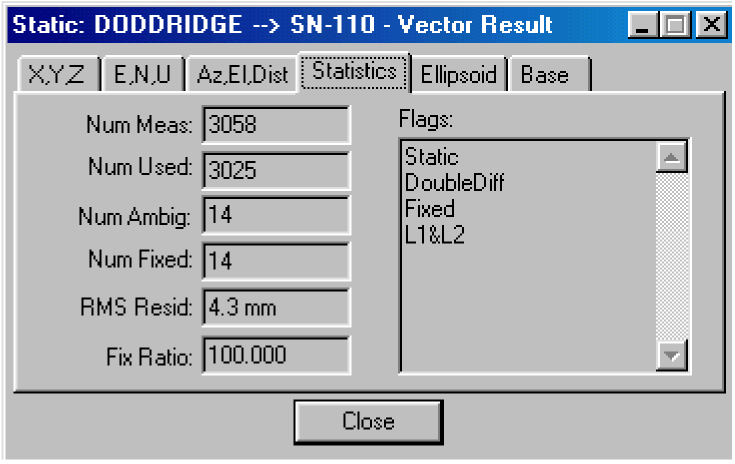


Figure 7-24

7.3.14.5 (Error) Ellipsoid

The (***Error) Ellipsoid*** panel will show:

- o Lengths, azimuths and elevations of the error ellipsoid's semi-axes
- o Lengths and azimuths of the semi-axes of the plane error ellipse (this ellipse is generated by projecting the error ellipsoid onto the horizontal place)
- o Length of the projection of the error ellipsoid on the local normal ("vertical projection length")

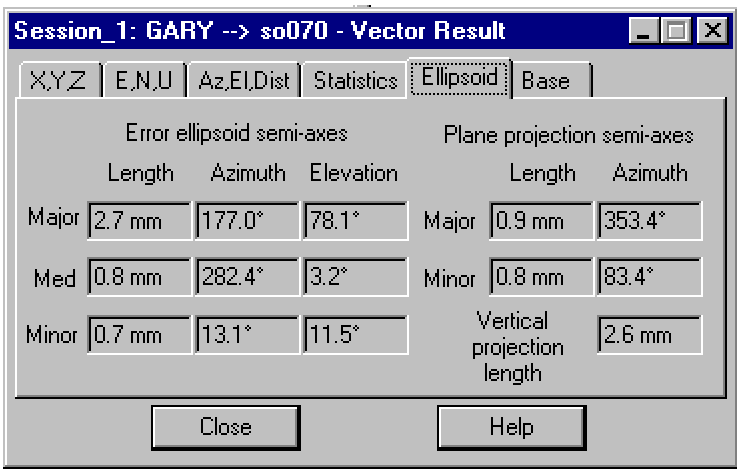


Figure 7-25

7.3.14.6 Base

The ***Base*** panel will show the absolute coordinates of the vector end-point which has been used as a *reference* when computing the vector. The coordinates are given in WGS84 (even if the vector has been computed using purely GLONASS data).

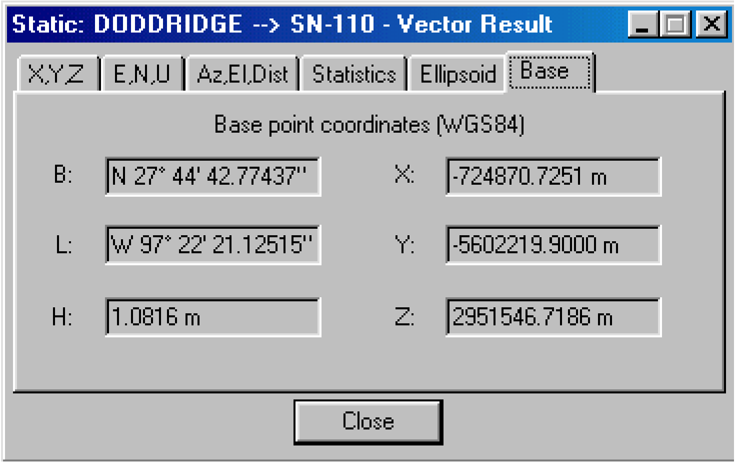


Figure 7-26

7.3.15 Properties

The ***Properties*** option allows the user to view the names of the vector's end points and its length. If the vector is unprocessed yet, its length will be calculated using the navigational coordinates of the end points.

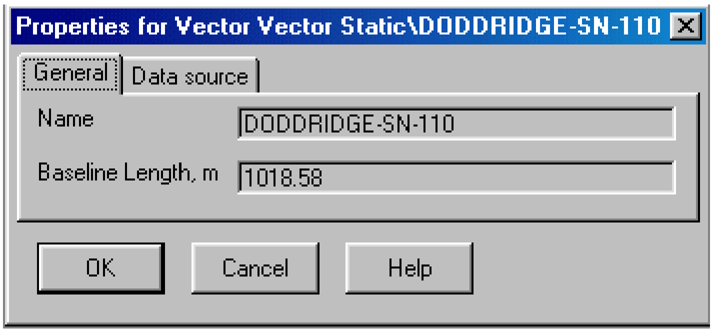


Figure 7-27

7.4 Operations on a group of Vectors

If the user selects more than one vector and then right-clicks on any one of them, the following menu will drop down:

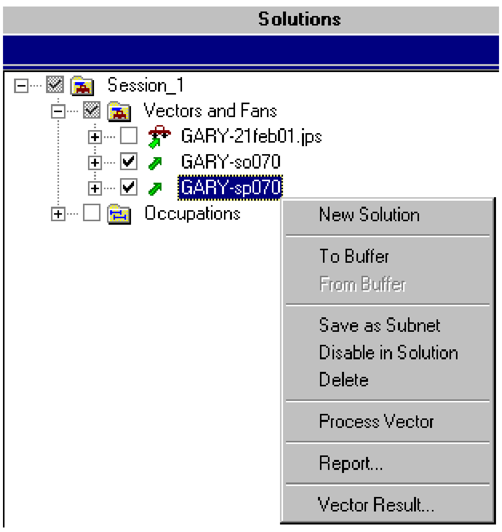


Figure 7-28

All of these options have been already explained in 7.3. Note that some of the menu options available for an individual vector will not be available for a group of vectors.

7.5 Operations on an individual Fan

If the user right-clicks on an individual fan, the following drop-down menu will appear:

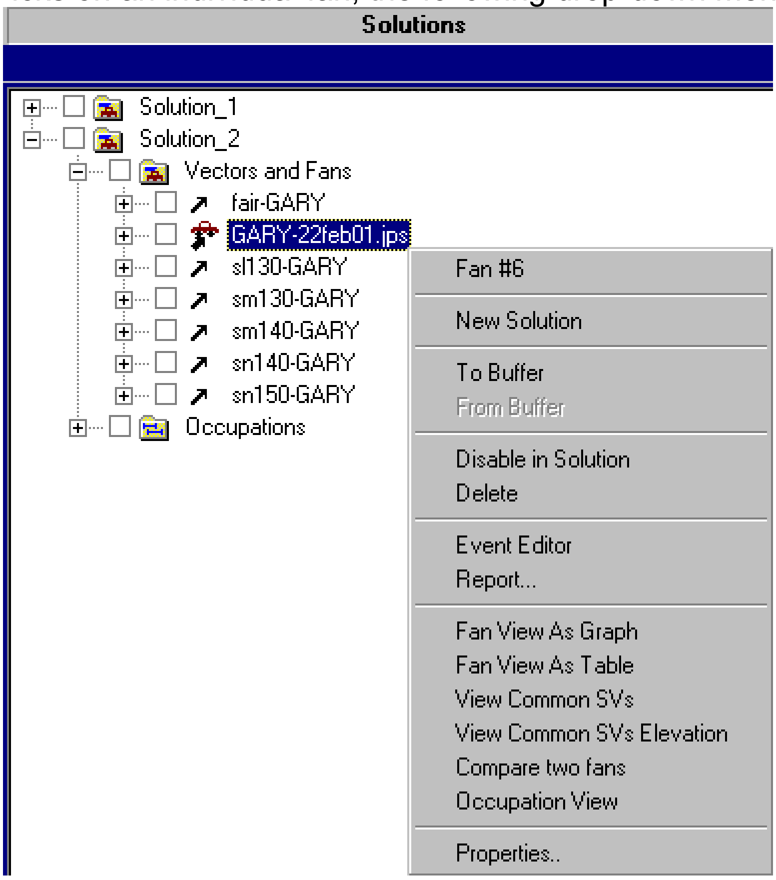


Figure 7-29

7.5.1 New Solution

This option is used to create a new (empty) solution.

7.5.2 To Buffer / From Buffer

The '*To buffer*' option allows the user the save the *checked fan* masks to the buffer. The user can later restore these checks by clicking on the '*From buffer*' option.

7.5.3 Disable in Solution

If the option ***Disable in Solution*** is applied to a fan, this fan will be excluded from further processing. In addition, this fan will be marked with the icon:

- , if it has not yet been processed,
-  , if it has been processed.

On the other hand, the option '***Enable in Solution'*** allows the user to re-enable fans.

7.5.4 Delete

Once the option ***Delete*** is selected for a fan, the following prompt will be displayed:

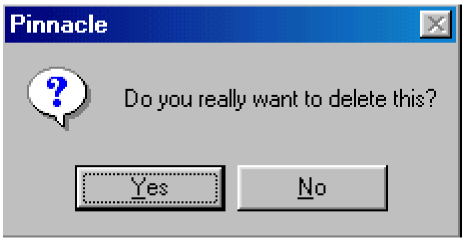


Figure 7-30

If ***Yes*** is selected, the fan will be permanently removed from the ***Solutions*** panel.

7.5.5 Event Editor

This module is incorporated into Pinnacle to compute the position of the photo camera's perspective center.

The ***Event Editor*** first interpolates the coordinates of the antenna phase center to the event reception times. ***Event Editor*** then calculates the coordinates of the camera's perspective center at the time of exposure by using the measured orientation angles and by reducing the position of the antenna to the position of the camera.

For detailed information about the ***Event Editor***, see [2].

7.5.6 Report

With the ***Report*** option, the user can display the computed trajectory on the screen or save it to disk in various ascii, html or binary formats.

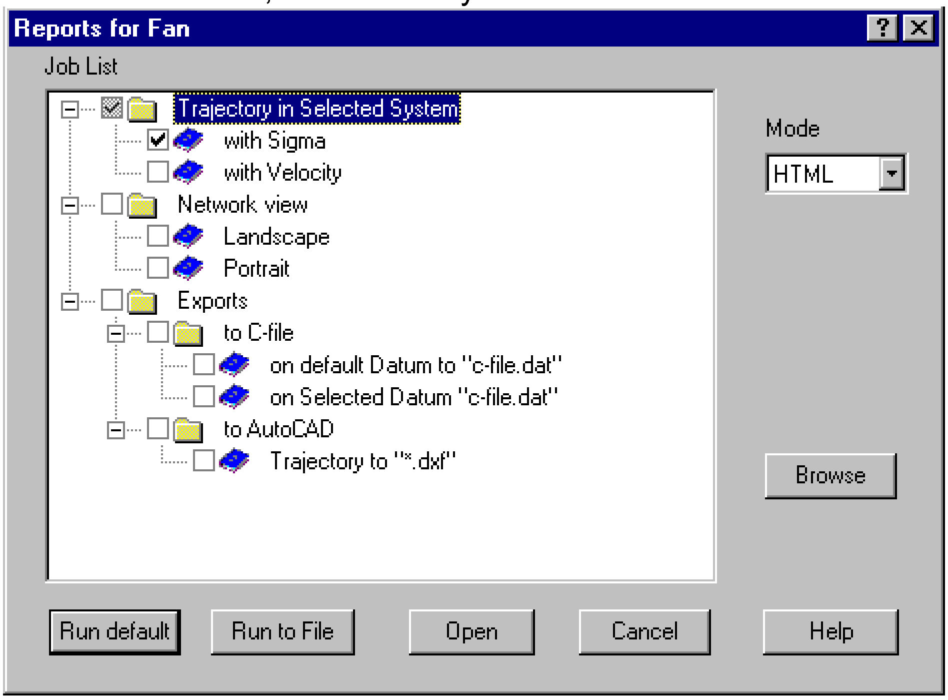


Figure 7-31

7.5.7 Fan View (Graph)

After a trajectory has been computed, the user may want to run the ***Fan View (Graph)*** option to view the following data (as functions of time):

- ***Number of SV's*** - Total number of satellites used in trajectory computation
- ***PDOP*** - Position dilution of precision

- ***RMS*** -Trajectory RMS error (i.e., the square root of the trace of the variance-covariance matrix obtained for the corresponding trajectory point)
- ***Velocity*** - Magnitude of the rover's velocity. Velocity is calculated as the time derivative of the smoothed X-, Y-, Z-coordinates. A polynomial running average filter is used for trajectory smoothing.
- ***H*** – *Up*-component (or *height*) of the rover in the local system with the origin at the base.
- ***X-,Y-,Z-***components of the computed trajectory in the cartesian system (WGS84)
- ***Occupations*** **–** occupation times against the receiver serial numbers

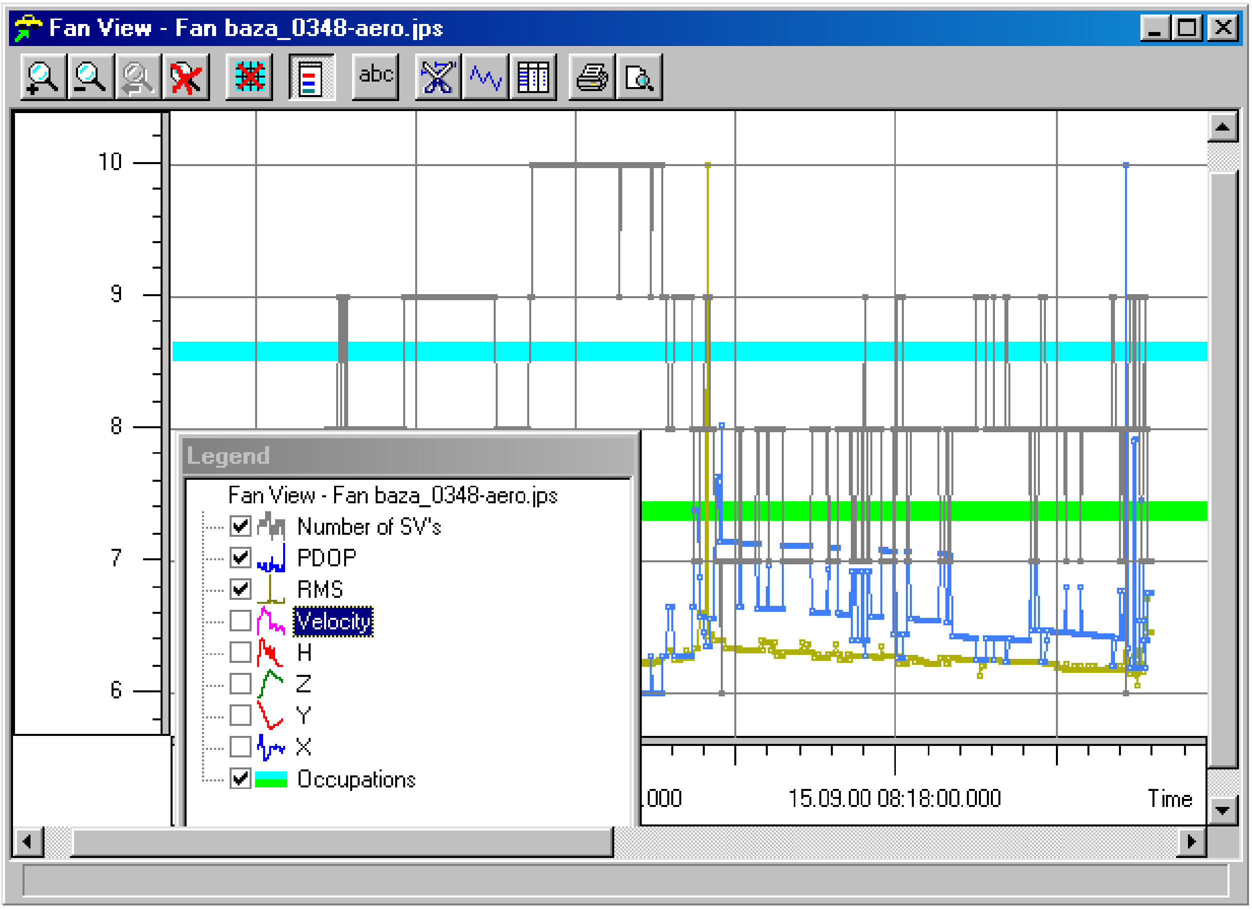
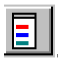


Figure 7-32

In fact, the user does not have to handle all nine parameters (plots) simultaneously (in this case the fan view would probably look 'oversaturated' with graphical data). The user can easily switch plots on and off the using the checkboxes in the **Legend** window. To open this window, the user must click on the icon .

Example. Suppose there are currently two plots in the fan view ('occupations' and 'number of satellites') and the user needs to draw another one, '*Velocity*'. To do this, the user must simply check the desired parameter in the **Legend** window. Alternatively, the user can right-click on this parameter and select the '*Show*' option from the small pop-up menu that will appear:

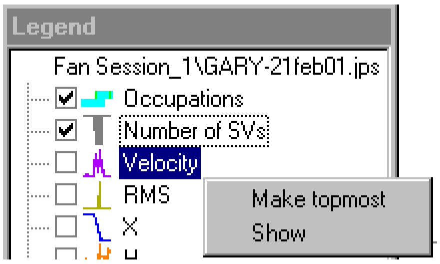


Figure 7-33

Note that the axes in the fan view will correspond to the first of the plots enabled in the ***Legend*** window. To ensure that the axes will match the desired plot, the user must make this plot topmost in the ***Legend*** window's list. This can be achieved with the ***Make topmost*** option.

Similarly, the user can remove unnecessary plots from the fan view by deselecting them (either by removing the corresponding checkmarks or by using the '*Hide'* option).

Note that such options as ***Zoom in/out***, ***Switch legend on/off***, etc. are available not only via the toolbar icons at the top of the fan view window but also via the pop-up menu that can be invoked by right-clicking somewhere in an empty area of the fan view window. This menu is shown below:

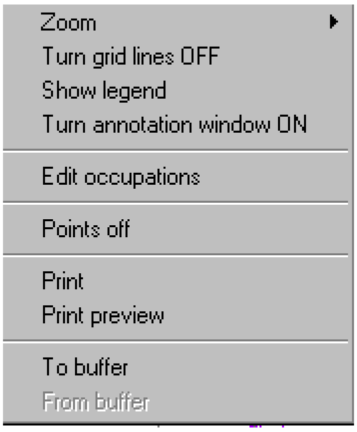


Figure 7-34

The user can change from ***Fan View (Graph)*** to ***Fan View (Table)*** by clicking on the icon .

7.5.8 Fan View (Table)

As the name suggests, this feature allows the user to view the fan data in a tabular form:

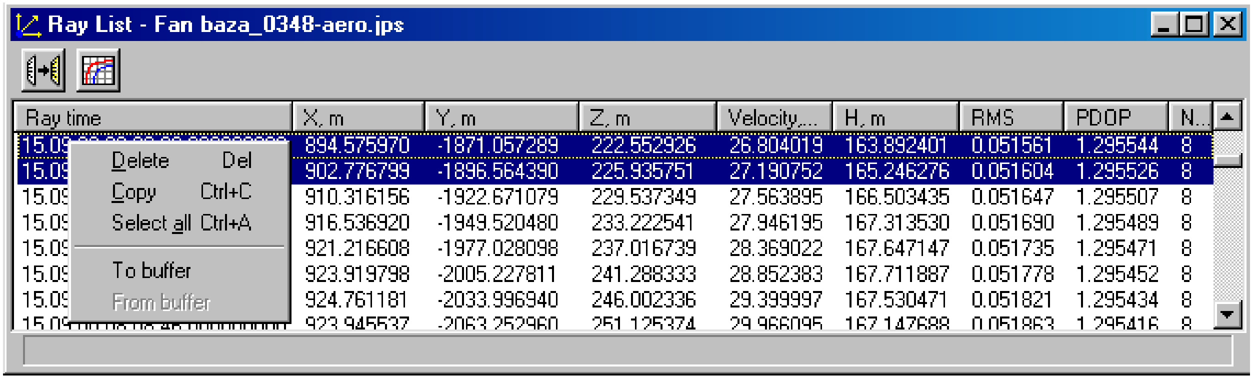


Figure 7-35

The user can highlight the desired lines (using the 'shift' and 'ctrl' keys if necessary) and copy the selected data to the clipboard. Alternatively, the data can be copied to the clipboard by using the icon on the toolbar.

The user can change from ***Fan View (Table)*** to ***Fan View (Graph)*** by clicking on the icon.

7.5.9 Common SVs (totals)

With this option, the user can view the total numbers of 'common' GPS and GLONASS satellites whose elevations exceed the mask specified in the '*Mode'* panel of the corresponding '*Process Properties*' window. 'Common satellites' are the satellites for which simultaneous measurements at the base and the rover are available.
In the ***Common SVs (totals)*** window, the totals of GPS and GLONASS satellites are marked in blue and red, respectively.

7.5.10 Common SVs (Elevations)

The option ***Common SVs (Elevation)*** allows the user to view the elevations of the common satellites available to compute the given fan. The dotted line designates the elevation angle mask as specified in the '*Mode'* panel of the corresponding '*Process Properties*' window.

7.5.11 Compare Two Fans

With this option, the user can compare two 'related' fans computed in either of the following two scenarios:
Scenario #1: The two fans compared have been computed using the same raw data measurements for the base and the rover yet with different process settings.
Scenario #2: The two fans have been computed using the same *rover data* but with different *base data*.
Note that two fans can be compared even if they belong to different ***Solutions*** and ***Networks***. However, they both must reside in the same Pinnacle project.

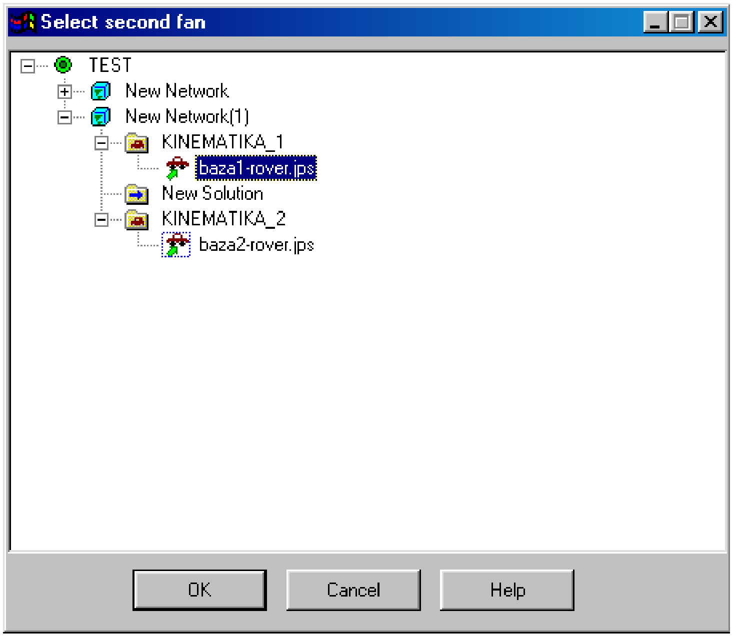


Figure 7-36

After the first of the two fans to be compared is selected (this will be marked as ), the user must then select the other one. If both the fans have been selected correctly, the ‘OK’ button will become active. After the user presses ‘OK’, Pinnacle will start comparing the fans. The results of the comparison will be displayed in the following form:

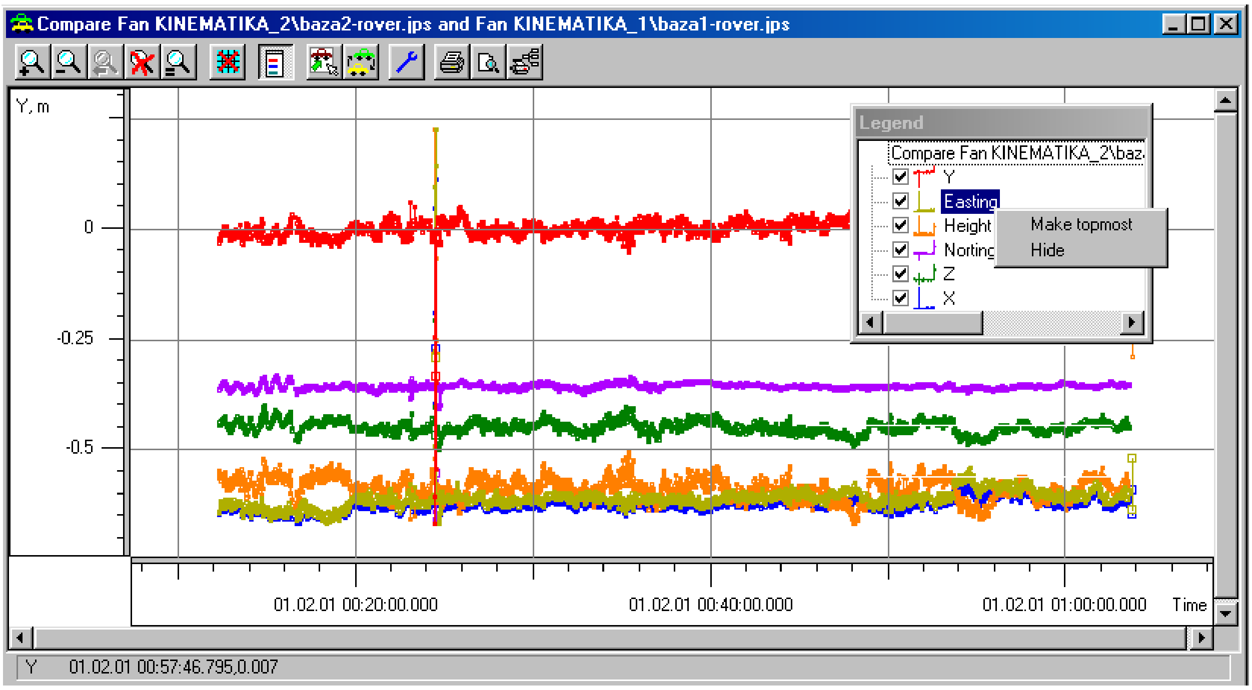


Figure 7-37

The differences will be presented in the cartesian (X,Y,Z) and local (E,N,U) coordinate systems.

Note. The vertical axis will match only the first of the graphs drawn in the ‘Compare Fans’ window (it is the Y-component in the above screenshot). The other graphs are not precisely referenced vertically in this window (their offsets from the X-axis are arbitrary). To get a meaningful vertical axis for a specific graph (component) , make this graph topmost in the ***Legend*** list.

7.5.12 Occupation View

The option ***Occupation View*** serves to view the occupations corresponding to the given fan. Note that the option ***Occupation View*** for fans has much in common with its counterpart for vectors (see 7.3.12).

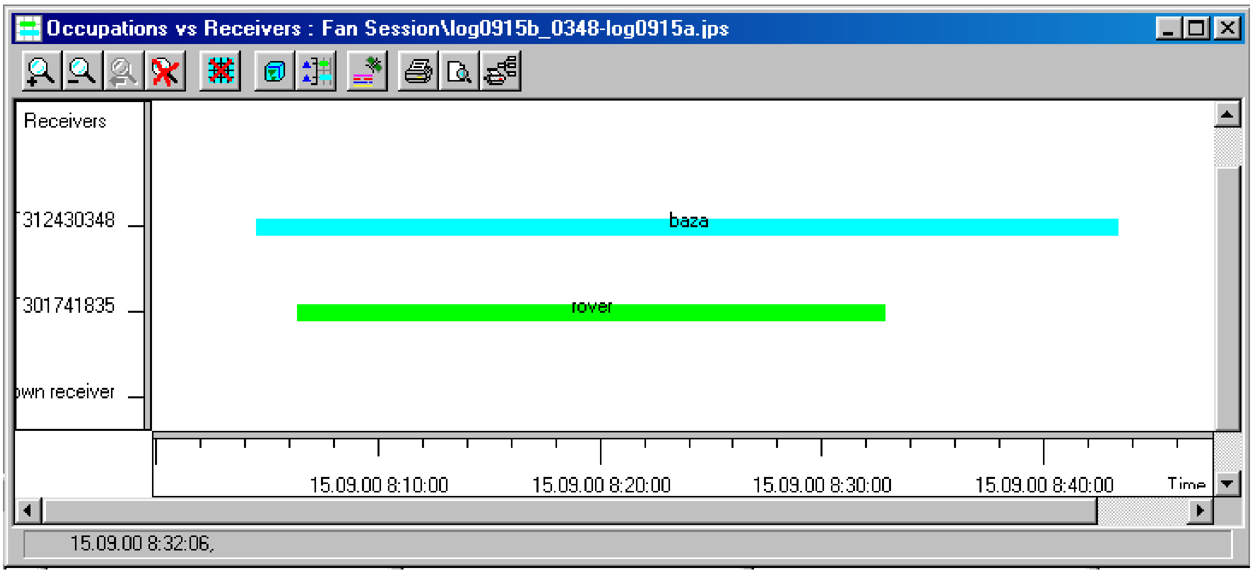


Figure 7-38

7.5.13 Properties

From the ***Properties/General*** panel the user will know the following information:

- name of the rover (trajectory) file associated with the given fan
- number of epochs ("rays") existing in the fan

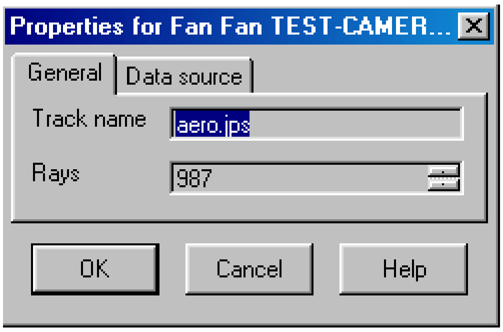


Figure 7-39

7.6 Operations on a group of Fans

If the user selects more than one fan under the ***Fans*** (or ***Vectors and Fans***) node, the following pop-up menu will appear:

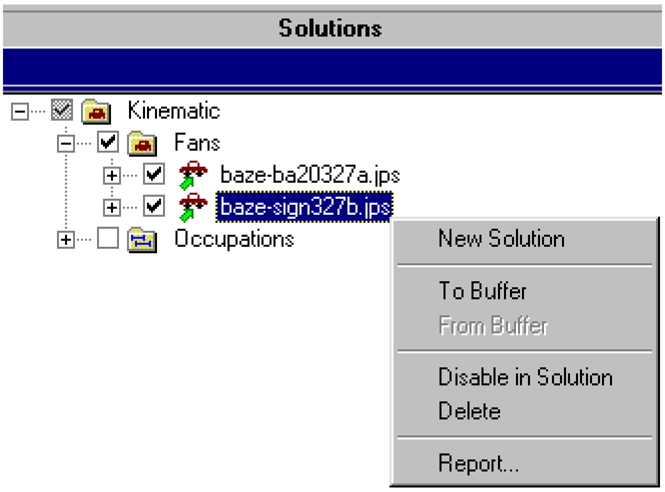


Figure 7-40

Note that this menu will not include all of the options available for an individual fan (see the menu shown in 7.5).

7.7 Operations on an individual Solution/Occupation

After the user clicks on a specific occupation under the Occupations node, the following pop-up menu will appear:

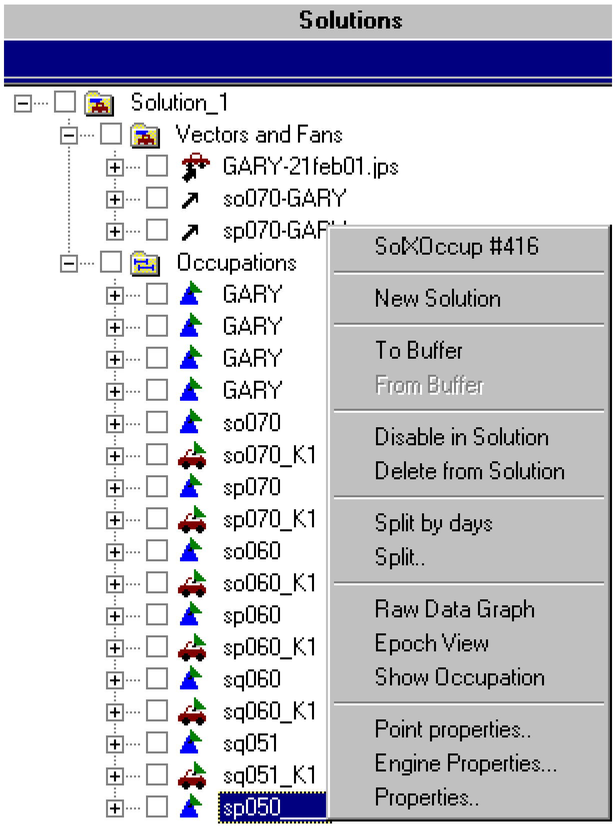


Figure 7-41

Note. The *'Point Properties…'* option will be unavailable for kinematic occupations.

7.7.1 New Solution

This option allows the user to create a new (empty) solution.

7.7.2 To Buffer / From Buffer

The '*To buffer*' option allows the user the save the *checked occupation* masks to the buffer. The user can later restore these checks by selecting the '*From buffer*' option.

7.7.3 Disable / Enable in Solution

If the user has applied ***Disable in Solution*** to an occupation or a group of occupations, they will not be used in further vector/trajectory processing. Disabled static and kinematic occupations will have the icons and , respectively.
Conversely, the option ***Enable in Solution*** is used to re-enable occupations.

7.7.4 Delete from Solution

As the option name implies, this option is used to permanently delete occupations from the ***Solution***.

7.7.5 Split by day

The ***Split by day*** option is intended to divide very long occupations into 24-hour splits (splits will be made at the day boundary). This option is identical to its counterpart described in 6.4.

7.7.6 Split

It allows division of an occupation into two parts. The ***Split*** option is identical to its counterpart described in 6.4.

7.7.7 Raw Data Graph

Raw Data Graph is a powerful graphical tool incorporated into Pinnacle. For details, see 10.

7.7.8 Epoch View

This option allows the user to view the entire raw data available for the given occupation in the following tabular form:

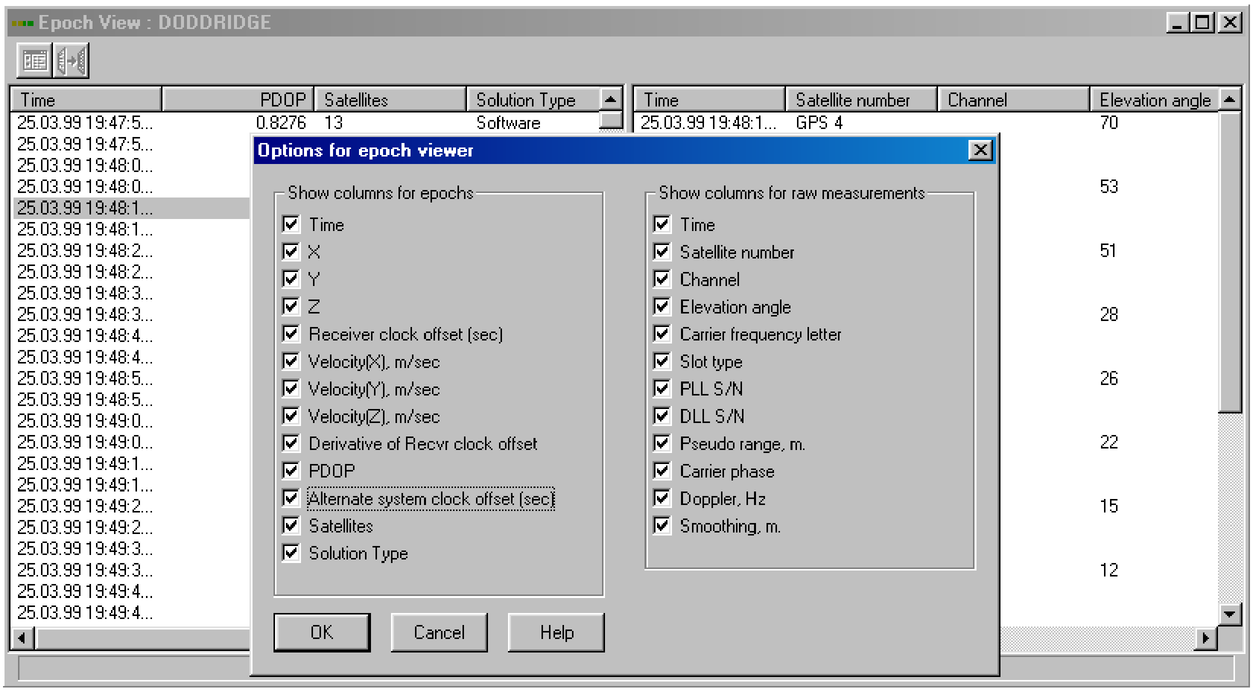


Figure 7-42

The user may remove unnecessary data from the *Epoch View* table by unchecking the corresponding checkboxes in the *Options* dialog box. To open the *Options* dialog box, right-click somewhere in a free area of the *Epoch View* window and select ***Options*** from the pop-up menu that will appear.

7.7.9 Show Occupation

If the user selects ***Show Occupation*** for an occupation in the Solutions panel, Pinnacle will highlight the *prototype* occupation in the ***Raw Data Occupations*** panel.

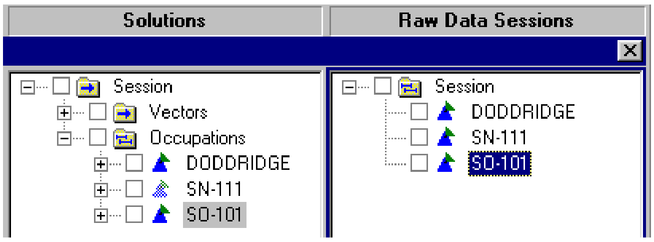


Figure 7-43

7.7.10 Point Properties

This option is available for static occupations only.
After the user clicks on this option, a five-panel ***'Properties for point <name>'*** window will be opened.

7.7.10.1 'General' panel

The user can view or rename the point name in this panel.

7.7.10.2 'Navigational Coordinates' panel

This panel will show the point's ***navigational coordinates***. These coordinates are obtained by averaging the standalone positions computed by the receiver over the occupations corresponding to this point.
With the ***Coordinate Calculator*** button, the user can easily convert the navigational coordinates from WGS84 into another coordinate system.

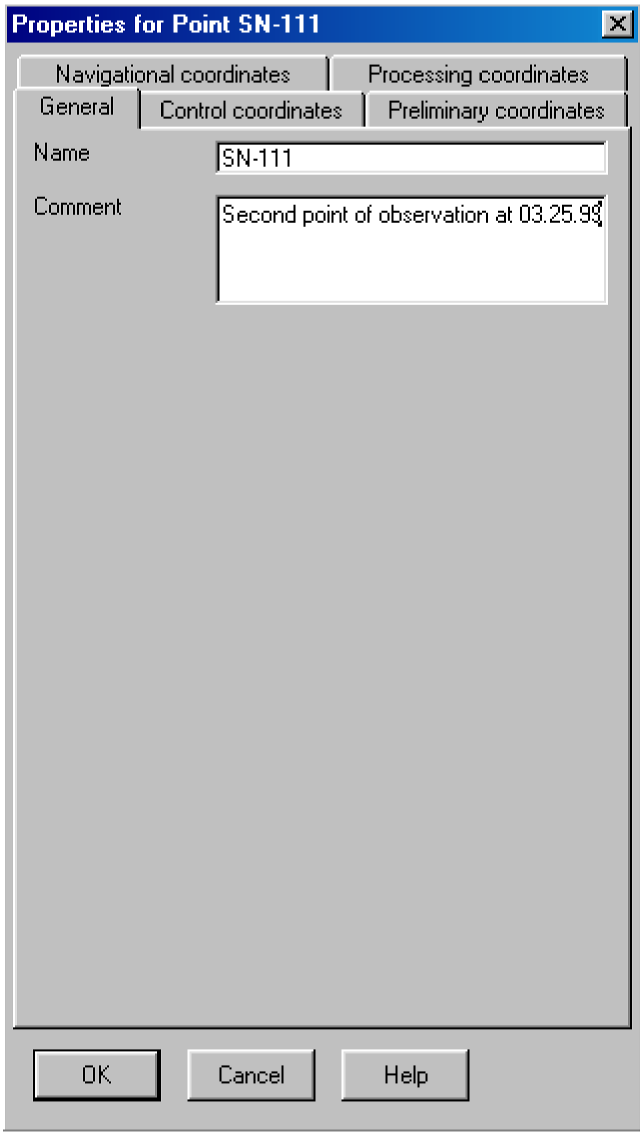


Figure 7-44

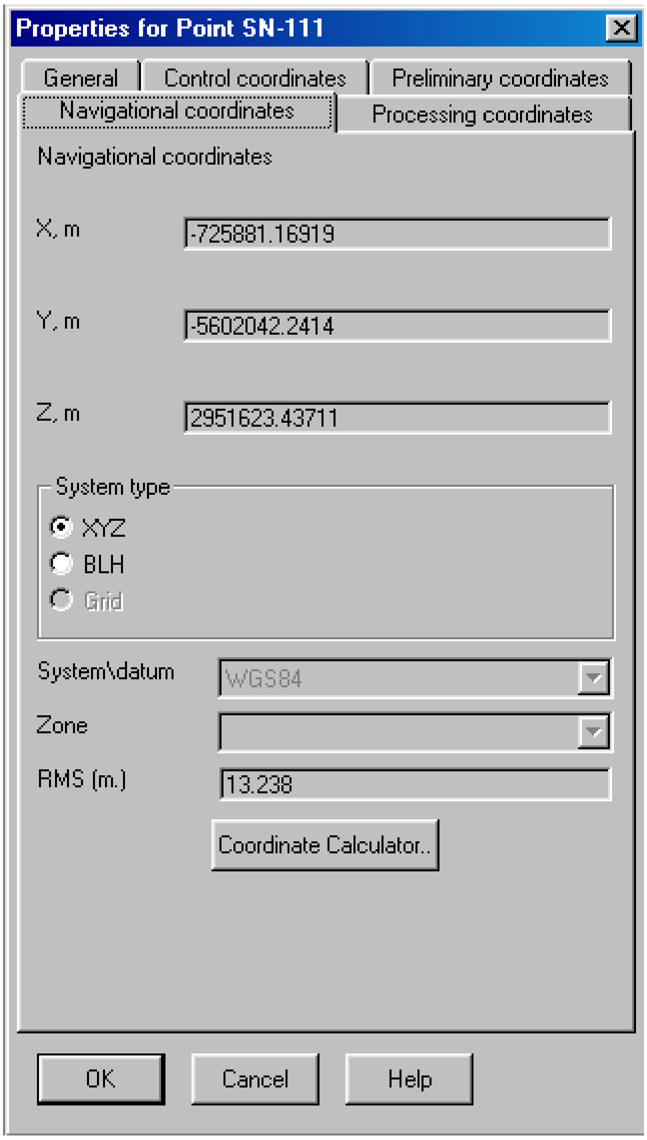


Figure 7-45

7.7.10.3 'Processing coordinates' panel

This panel will show the point's ***processing coordinates*** if available.
These coordinates are obtained by summing the *processed* vectors' components with the coordinates of the *seed* (or *control*) point used by the Pinnacle engine as a reference when computing these vectors.
Note the large differences (of a few orders of magnitude) between the rms position errors for navigational and processing coordinates.
Also note that the point's processing coordinates may or may not change after Pinnacle has re-processed one or more vectors connecting some of the earlier processed point (or the *seed/control* point) with the given point. Processing coordinates will be updated only if the newly estimated rms position error for the point is smaller than it was before recomputing the vector(s). Otherwise Pinnacle will maintain the previous processing coordinates/rms position error in the ***Processing coordinates*** panel and the network's ***Points List***.
However, if the user wants to remove the current processing coordinates of the point altogether, this can be done either by clicking on the ***Clear*** button in the ***Processing***

coordinates panel or by selecting the option Clear processing coordinates from the network's menu.[7]

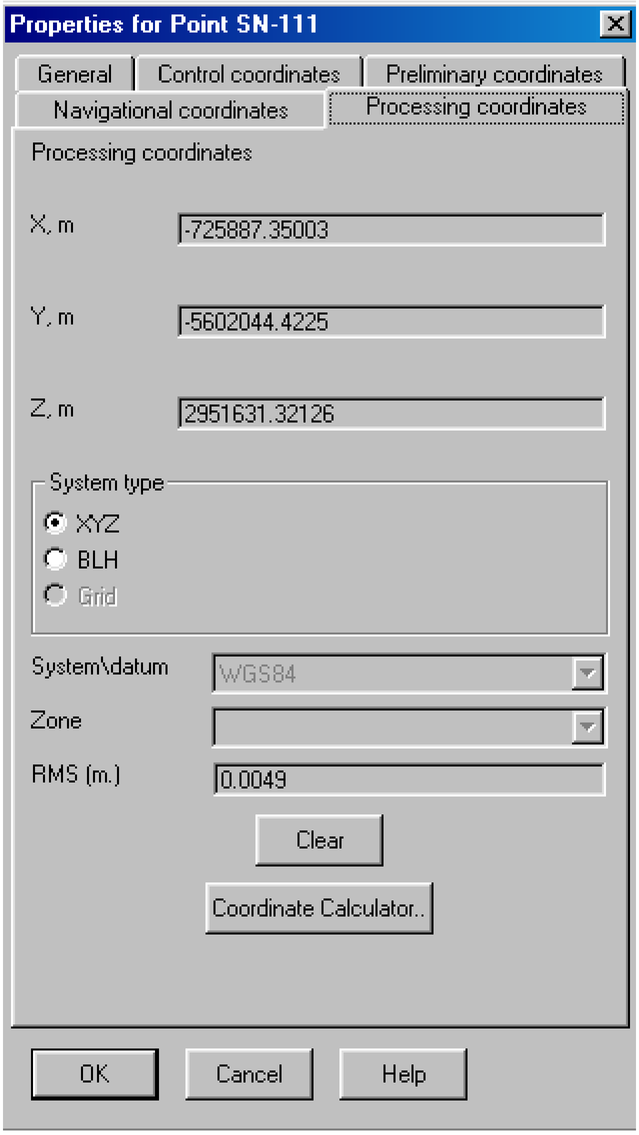


Figure 7-46

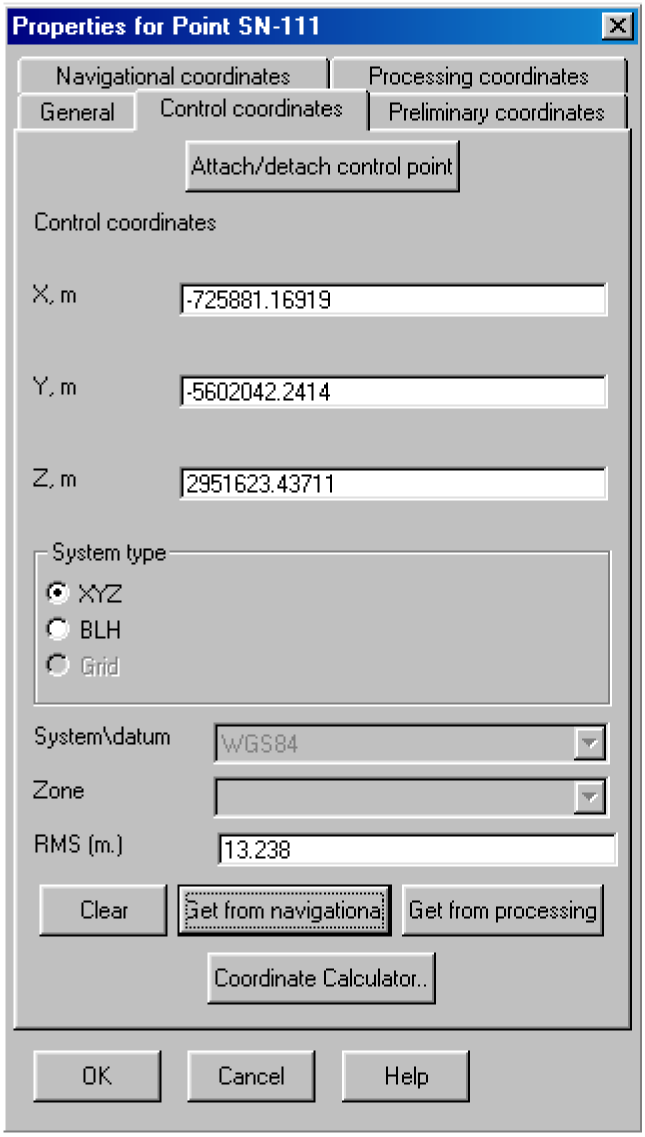


Figure 7-47

7.7.10.4 'Control Coordinates' panel

In this panel the user may specify *control* for some of the subnet's points. There are three methods of doing this, specifically, by using:

- o Navigational coordinates
- o Processing coordinates
- o Control Data List(s).

#1: Using navigational coordinates.

Press the button Get from navigational.

---

[7]) The user can open this menu by right-clicking on the network name in the left-hand most panel of Pinnacle's main window.

In the X, Y, Z edit boxes the navigational coordinates to be used as contol for the point once the user presses the 'OK' button will appear.
The user can then edit the coordinates and the rms error before pressing 'OK'.
To detach the earlier specified control, press the 'Clear' button.

#2: Using processing coordinates.

Press the button Get from processing.
(Steps are the same as above)

Note: Control specified in #1 or #2 will be valid for the subnet's points only "within the *Solutions* panel", i.e. when computing vectors and trajectories. This control will NOT be effective when adjusting the corresponding subnet.

#3: Using a Control Data List.

(Assuming the user has already created an appropriate control data list.)

Press the button Attach/detach control point.
The ***'Attach points: Select Control Data Lists'*** window will appear on the screen.

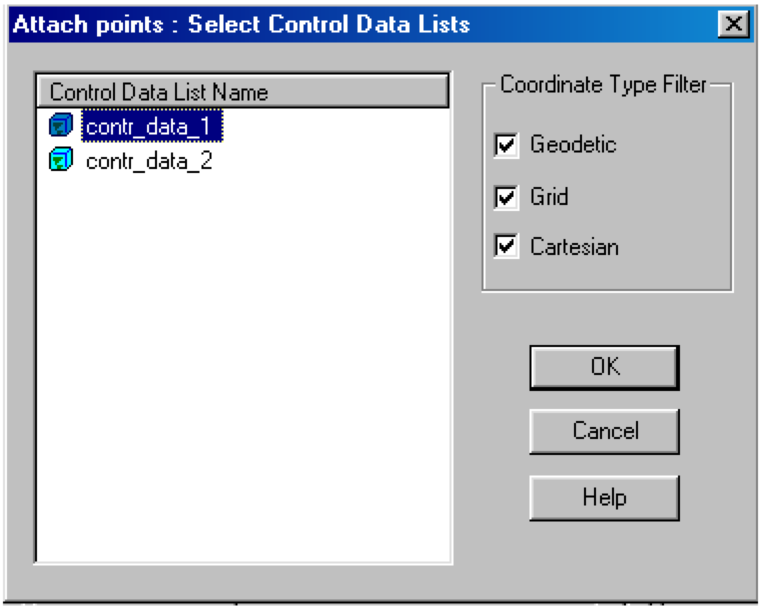


Figure 7-48

After the user selects the desired Control Data List and presses 'OK', the ***Attach Points to Control Points Items*** window will be opened. Then from the ***Points to attach*** panel, the user must select the point to which control will be attached. Pinnacle will then automatically identify and highlight the control point item that best matches the point's coordinates. Note that this control point item will be shown topmost in the ***Control point Items*** panel.

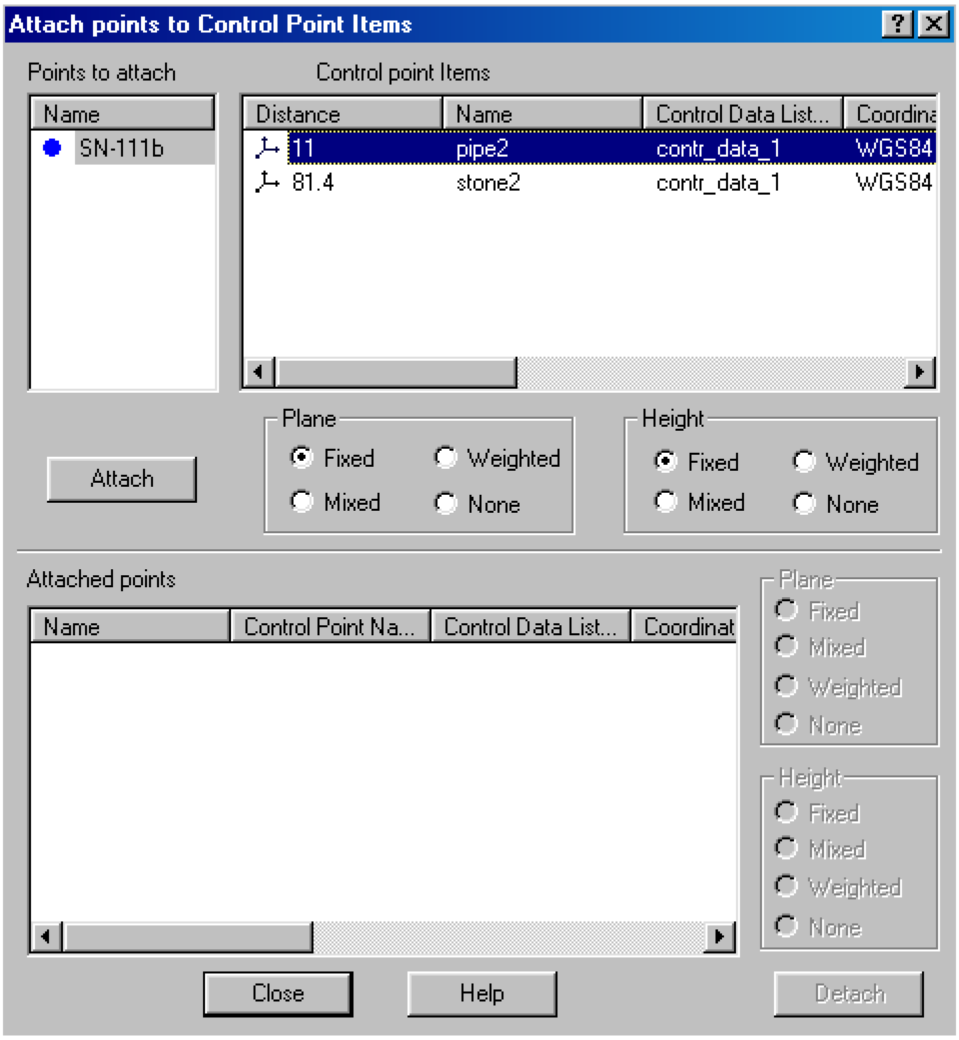


Figure 7-49

After pressing [Attach], these control coordinates will be displayed in the ***Control coordinates*** panel. The rms position error shown in this panel will be computed based on the following equation:

$$RMS = \sqrt{(Sigma(X))^2 + (Sigma(Y))^2 + (Sigma(Z))^2} \;,$$

where $Sigma(X), Sigma(Y), Sigma(Z)$ designate the rms errors of the coordinates borrowed from the ***Control Data List***.

Note that control established in #3 will be valid throughout the entire network (i.e. not only when computing vectors and fans but also when adjusting the corresponding subnets).

The button [Detach] in the '*Control Coordinates'* panel is used, as its name implies, to cancel (detach) control specified via a control data list.

7.7.10.5 'Preliminary coordinates' panel

The ***Preliminary coordinates*** panel is mainly used when planning a project. Such coordinates are always entered manually, i.e. they are not automatically computed by Pinnacle.

There are two ways to specify preliminary coordinates for a point.

1. Through the ***Points list***:

- o Right-click on the corresponding network name in the ***Network*** panel and select ***Points List*** from the pop-up menu.
- o Right-click somewhere in an empty area of the ***Poins List*** window and choose ***New Point*** from the pop-up menu that will appear:

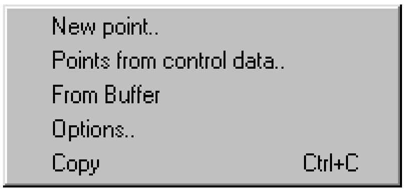


Figure 7-50

- o Enter the point name and, in the ***Preliminary coordinates*** panel, the point's preliminary coordinates.

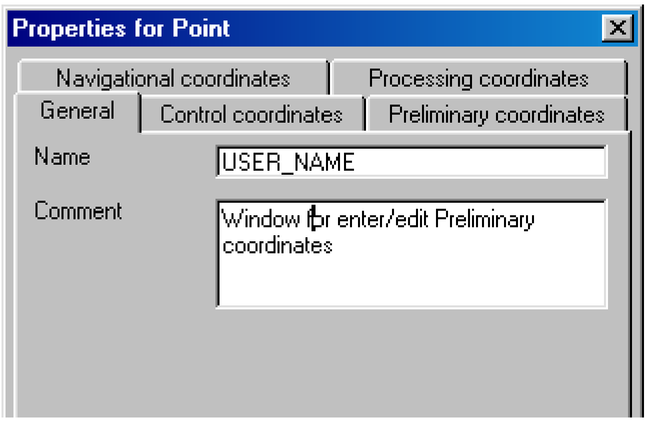


Figure 7-51

2. Through the ***Network View*** window invoked from the *SubNets* panel.
   - o Right-click on the corresponding subnet node and select ***Network View*** from the pop-up menu that will appear.
   - o In the ***Network View*** window, activate the ***Point drawing mode*** by clicking on the icon .
   - o Move the cursor onto the desired location in the ***Network View*** and click once. (Note that the geographic coordinates of the location the cursor points to will be shown in the bottom-left corner of the ***Network View*** window.) Enter the point's name and coordinates through the 'Properties for point' window.

7.7.11 Engine Properties

The ***Engine Properties*** window comprises two panels, ***Timing*** and ***Satellites***.

7.7.11.1 'Timing' panel

In the ***Timing*** panel, the user can view the following data for a given occupation:

- o Start and end times in (HH:MM:SS),
- o Length of occupation in (HH:MM:SS),
- o Recording interval (a.k.a. epoch interval)
- o Total number of epochs, and other information.

Here the user can *reset* the start and end times for this occupation thus instructing the Pinnacle engines to use only ***part*** of the entire occupation when computing the

corresponding vectors and trajectories. Also, the user can specify a decimation factor N ("epoch gap") thus forcing the engines to use only every N-th epoch for this occupation (when processing vectors and fans which are dependent on this occupation).
Note that the *effective* start and end times for the occupation can be set using either the spin-boxes or the sliders. Normally the sliders are used for coarse tuning and the spin-boxes for fine-tuning.
If the user wants to cancel all the settings previously made in this dialog window, this can be achieved by pressing the ***Restore Default*** button.

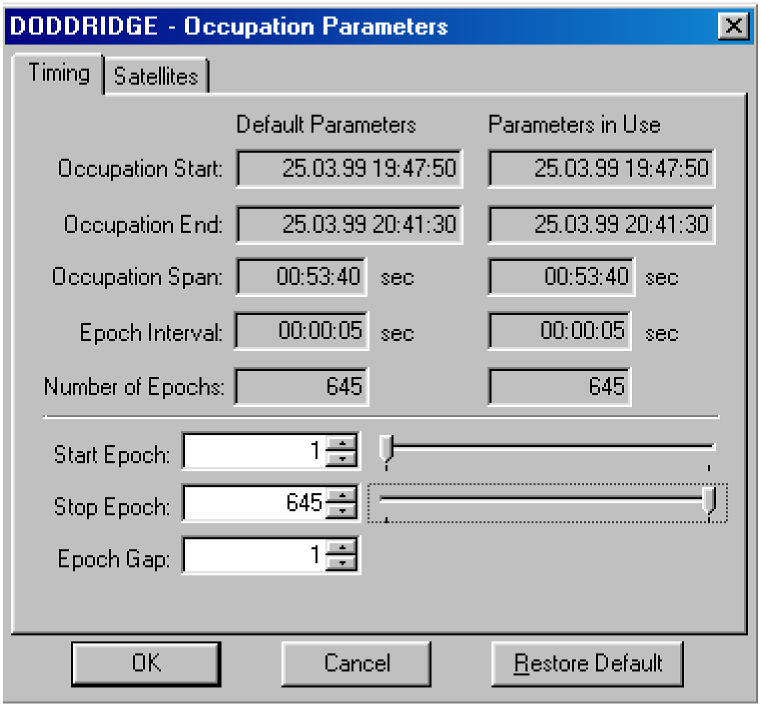


Figure 7-52

7.7.11.2 'Satellites' panel

This panel allows the user to view satellites for which raw data measurements are available over the occupation. Specifically, this panel will show:

- Start time of the interval during which the given satellite was being acquired
- End time of the interval during which the given satellite was being acquired
- Length of the interval during which the given satellite was being acquired
- Number of epochs for each acquired satellite
- Satellites' elevations (at start time, at end time and the maximum value over the availability interval)
- Ephemeris type/quality indicators and comments

If there are only broadcast ephemerides for a satellite, this satellite will be marked with  and the *Comments* column will contain the line "*Broadcast, Not precise".*

If there are only precise ephemerides for a satellite, this satellite will be marked with  and the *Comments* column will contain the line "*No broadcast, Precise".*

If there are both precise and broadcast ephemerides for a satellite, this satellite will be marked with  and the *Comments* column will contain the line "*Broadcast, Precise".*

If there are no ephemeris data for a satellite, this satellite will be marked with and the *Comments* column will contain the line "*No ephemeris*".

There are some limitations on Pinnacle's engines's ability to use precise orbits for the GLONASS satellites. This is due to the fact that some agencies (e.g., *ESOC* and *GeoForschungsZentrum, Potsdam*) often produce 'incomplete' precise GLONASS ephemeris files (such files may not contain time corrections for some satellites over some time intervals). Therefore, Pinnacle's engines will use a precise GLONASS ephemeris if and only if the corresponding broadcast ephemeris is also available in the project. Thus the following rule applies:
When using precise GLONASS ephemerides for a Pinnacle project, make sure that they have been imported together with the corresponding broadcast orbits. Glonass satellites having both precise and broadcast ephemerides will be marked with .

Although Pinnacle allows use of precise GPS orbits alone (without additional broadcast ephemerides), the user must ensure that the corresponding SP3 file does not contain any 'fake' time corrections[8] in it. If any fake time corrections are overlooked by the user, Pinnacle will produce erroneous absolute positions and other corrupt occupation data.

With the ***SV Status*** checkboxes, the user can:

a) Exclude a satellite from further vector/trajectory processing (by checking ☑ The use of this SV is disabled).
After selecting the satellite, it will be marked with .

b) Forbid a satellite to be used as a reference (by checking ☑ Use as a reference SV is disabled).
After selecting the satellite, it will be marked with .

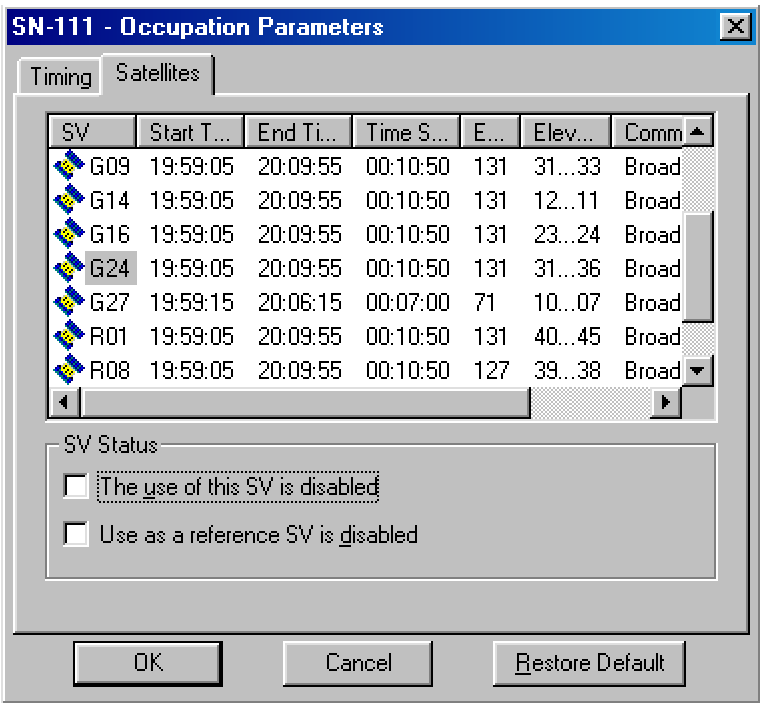


Figure 7-53

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[8]) such 'fake' time corrections are set to ***999999.999999*** in SP3 files

To cancel the settings made earlier, the user must press the button ***Restore Default.***

Note that the broadcast and precise orbits imported into a specific network of the given project will be shared by all networks created in the project. This means that the user will not need to load any 'additional' ephemeris data into a newly created network if it is known that the project database already contains ephemerides sufficient to process the raw data imported into this network.
Also note that each broadcast ephemeris has its own 'validity time'. When importing orbits, Pinnacle will check if the reference time parameters TOE and TOC[9] are consistent with the corresponding occupation times. If the orbits are found to be 'out-of-date', the Pinnacle import will report an error message.
Note the buttons  (Ephemeris Graphical Viewer) and  (Ephemeris Viewer) in the toolbar at the top of Pinnacle's main window. The first button allows, as it name implies, viewing of all available ephemeris data in a graphical form (see Figure 7-54). The second is intended to enable the user to view and edit the orbits in a tabular form (see Figure 7-55).

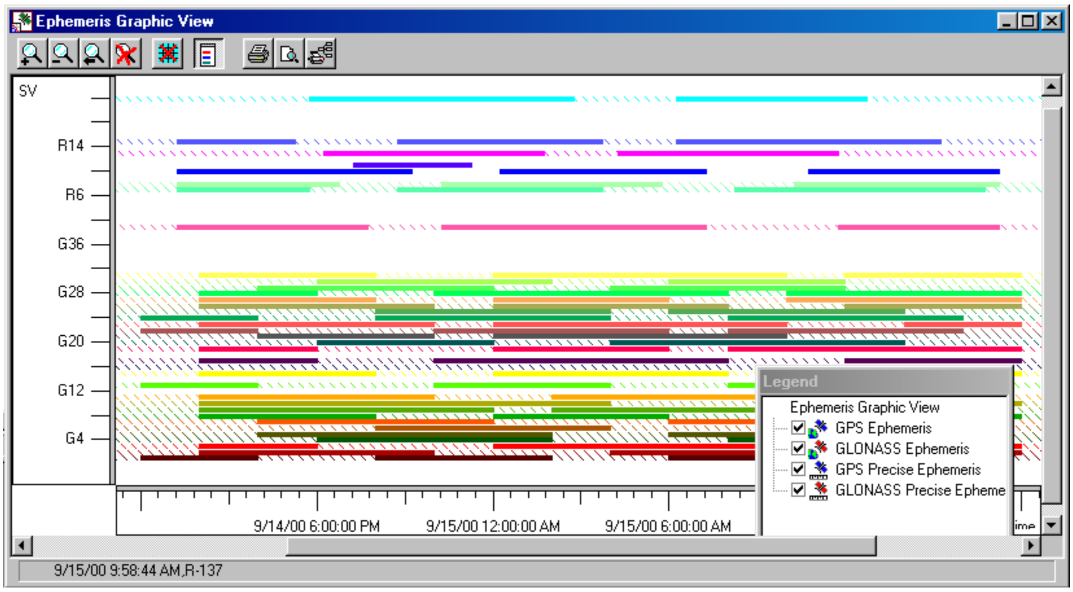

Figure 7-54

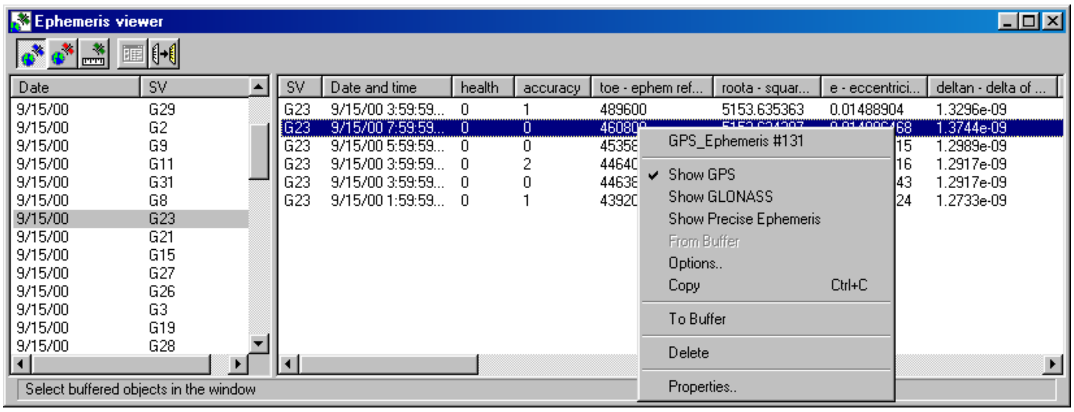

Figure 7-55

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[9] TOE - time of ephemeris. TOC – time of clock. These acronyms are used in the GPS ICD.

7.7.12 Properties

This option is identical to that described in 6.4. Selecting this option will invoke the seven-panel dialog window which is described in detail below.

7.7.12.1 'General' panel

Here the user can view and edit:

- Occupation name
- Point name
- Occupation type (static or kinematic), and more.

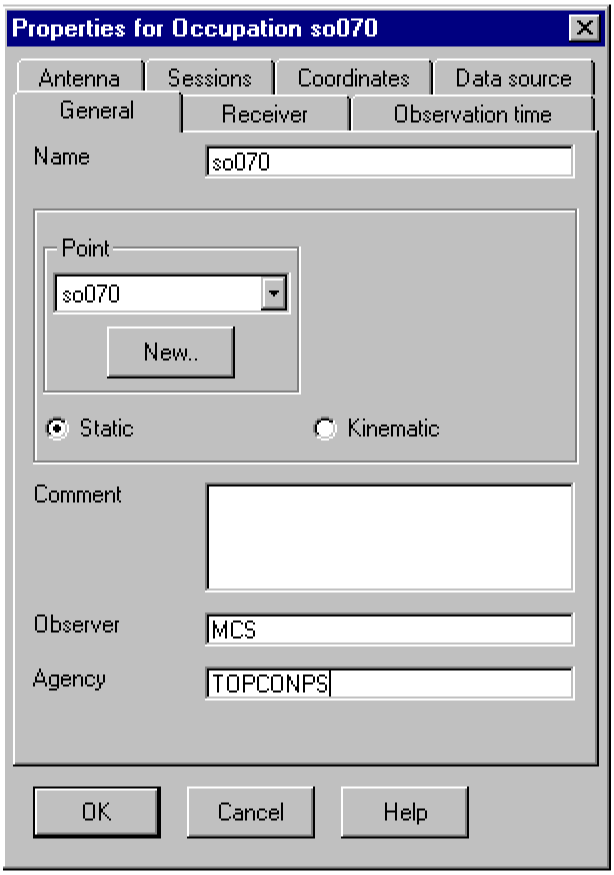


Figure 7-56

With the 'New…' button, the user can associate this occupation with another existing point (selecting it from the list box) or with a new point.
Note that when changing the occupation type from static to kinematic the '*Point'* listbox will become disabled (grayed out).

7.7.12.2 'Receiver' panel

Figure 7-57

In this panel the user can view and edit the receiver serial number.
Pressing the '*Properties…*' button will invoke a window showing among other information the full path of the raw data file containing the given occupation (see the example below).

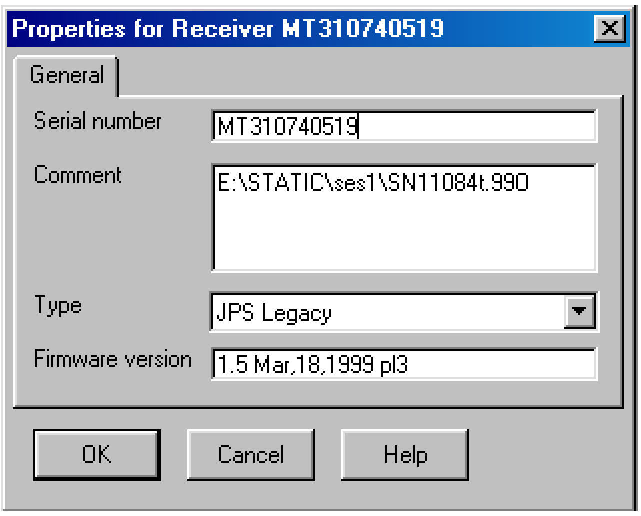


Figure 7-58

7.7.12.3 'Observation time' panel

This panel will show the following data:

- date and time of the start of the occupation
- date and time of the end of the occupation

- total number of epochs within the occupation
- recording interval (in milliseconds)

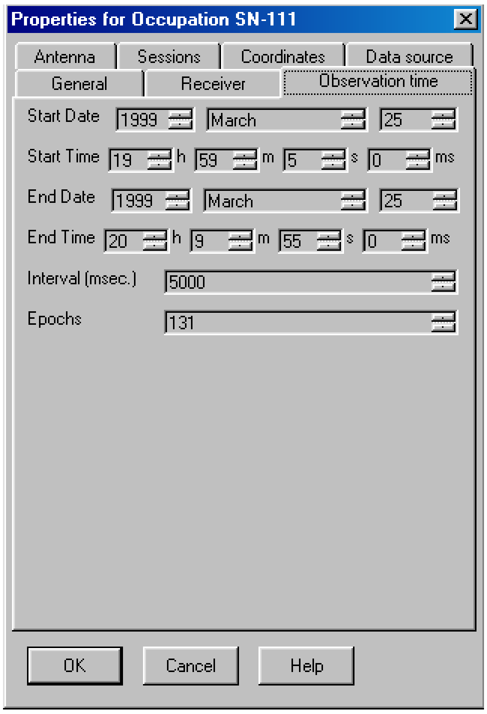


Figure 7-59

7.7.12.4 'Antenna' panel

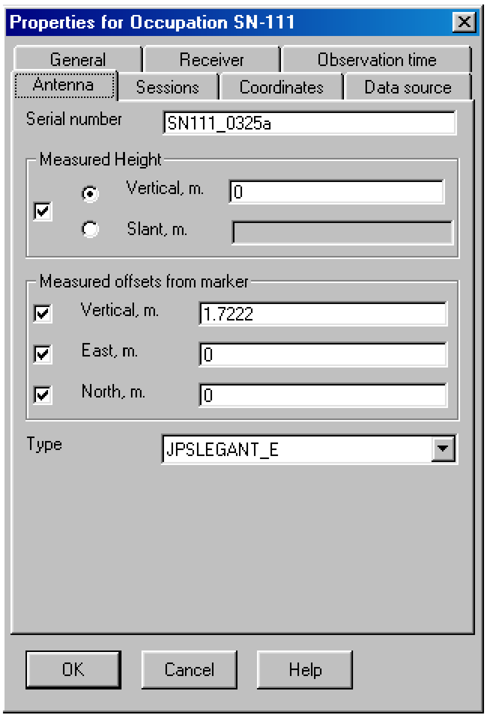


Figure 7-60

In this panel the user can view and edit various antenna parameters.
Note that the antenna height and the 'Marker to Sub-antenna point' offsets will not be active until the corresponding checkboxes are selected.
For how Pinnacle interprets the antenna parameters, see Figure 7-61.

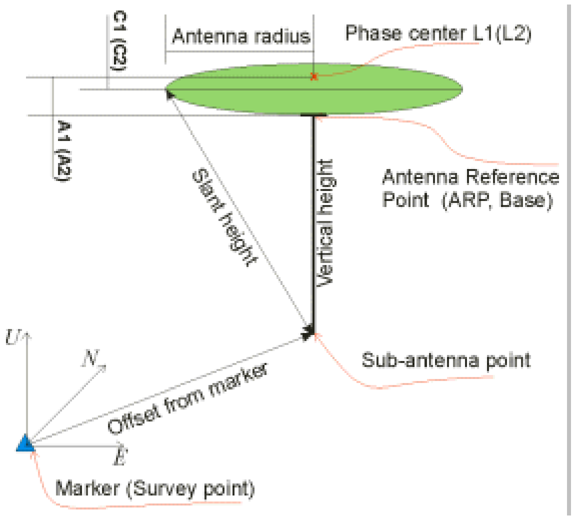


Figure 7-61

7.7.12.5 ‘ Coordinates’ panel

Here the user can view the navigational coordinates (averaged over the occupation) and their rms errors.

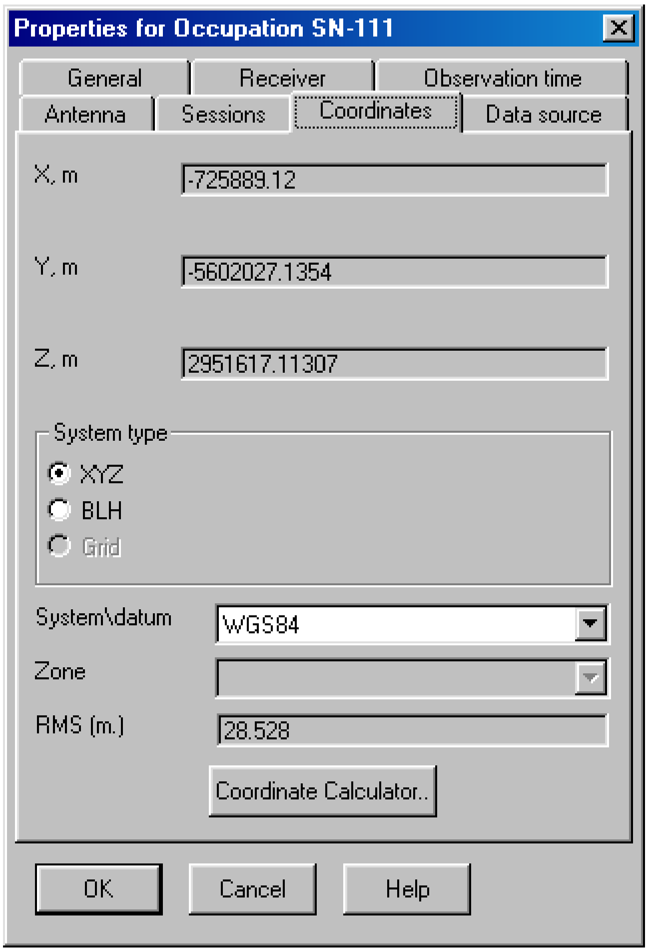


Figure 7-62

7.7.12.6 ‘Sessions’ panel

This panel indicates the raw data session that the given occupation belongs to.

7.7.12.7 'Data source' panel

As its name implies, this panel shows the full path name of the raw data file that the given occupation corresponds to.

7.8 Operations on a group of Solution/Occupations

If the user checks two or more occupations and then right-clicks on any one of them, the following pop-up menu will appear:

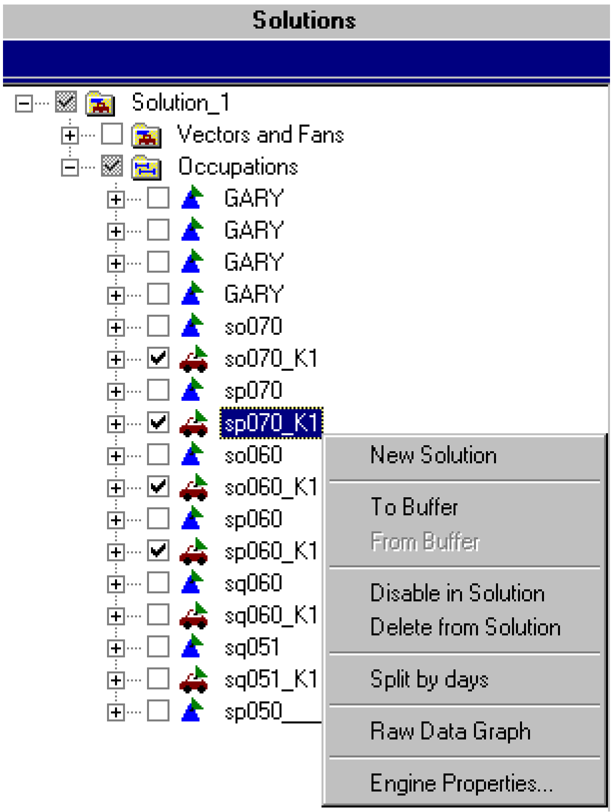


Figure 7-63

As can be seen from the above screenshot, this menu includes only *some* of the options available in a similar menu for individual occupations.

7.9 Operations on an individual Vector/Point

If the user expands a vector node and then right-clicks on either of the vector's end-points, the following pop-up menu will appear:

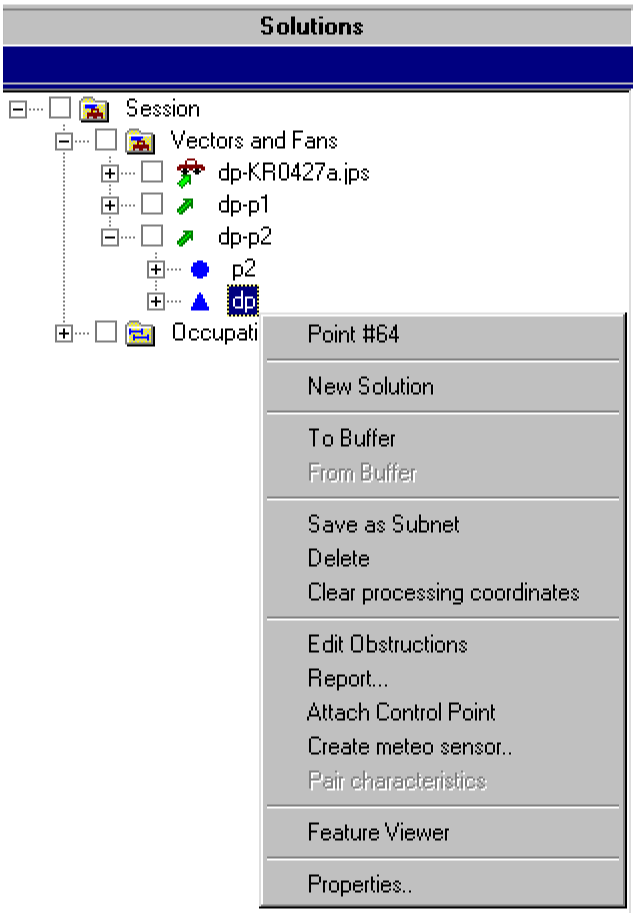


Figure 7-64

7.9.1 New Solution

As described in the above paragraphs.

7.9.2 To Buffer / From Buffer

As described in the above paragraphs.

7.9.3 Save as Subnet

This option is used to create a new Subnet and put the highlighted point into this Subnet.

7.9.4 Delete

When the user applies ***Delete*** to the highlighted point, Pinnacle will remove this point from the corresponding ***Network*** altogether. Therefore removing this point from the ***Network*** will also result in removing all the vectors associated with this point from the ***Solutions*** residing in the ***Network***. In the ***Raw Data Sessions*** panel, all the occupations that were originally associated with the deleted point will be changed from *static* to *kinematic*.

7.9.5 Clear processing coordinates

With this option the user instructs Pinnacle to remove the point's processing coordinates from the given ***Network.***

7.9.6 Edit obstructions

This option allows mission planning for a vector's end-point from within the Solutions panel. This is in fact rarely used.

7.9.7 Report

This option allows the user to obtain the coordinates of the selected point in the desired grid system. Note that this option is available for a vector's end-point only after this vector is checked. Otherwise an error message will be reported.

7.9.8 Attach Control Point

This option allows the user to specify control for a point by using the 'Control Data Lists' window as described in 7.7.10.4.

7.9.9 Create meteo sensor

N.B. <This feature will be removed from the next Pinnacle release>

7.9.10 Pair Characteristics (a.k.a. Baseline Characteristics)

Available for a vector's end-point only if this vector is checked.
This option allows the user to view how the vector's coordinates will change if its direction is reversed. This change is not trivial if the vector is presented in the ***Easting-Northing-Up*** or ***Distance-Azimuth-Elevation*** system.
Note that this option is available for both processed and unprocessed vectors.

7.9.11 Feature Viewer

This option allows the user to view all ***_FEA*** events available for the given point. For more information about this free-form event type, refer to the *GRIL User's Manual*, *Appendix E*.

7.9.12 Properties

This option is identical to the 'Point Properties…' option available for static occupations (see 6.4 for details).

7.10 Operations on an individual Vector/Point/Occupation

If the user clicks on a vector/point/occupation node, the following pop up menu will appear:

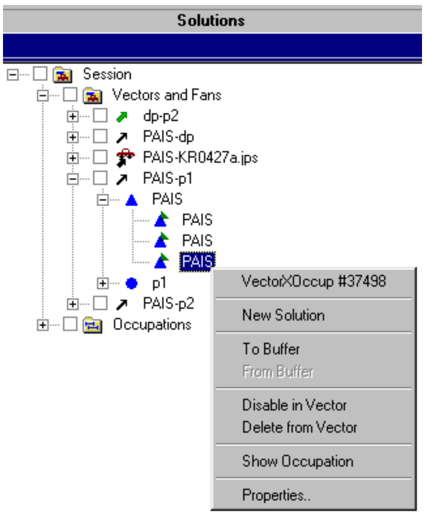


Figure 7-65

7.10.1 Disable / Enable in Vector

With this option, the user can disable and re-enable a particular occupation used for computing the corresponding vector.
After the user applies ***Disable in Vector*** to an occupation, this occupation will be marked with .

7.10.2 Delete from Vector

This option serves to prohibit use of the selected occupation for computing the corresponding vector.

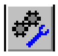
7.10.3 Show Occupation

This option allows the user to see the *prototype* occupation in the ***Raw Data Session*** panel.

7.10.4 Properties

This is identical to the option described in 6.4.

8 Engine Properties

After the engine type is selected, the user will be required to accomplish another, much more significant and complicated task: setting engine properties.
Engine properties can be set in different ways and from different parts of the graphical user interface. The user should bear in mind that each set-up will have a specific 'scope'. For example, the user may want to set the engine parameters for the entire project (by using the button  on the toolbar at the top of Pinnacle's main window), for a specific Solution (as mentioned in 7.1.9) or even for a specific Vector (see 7.3.13)[10].

8.1 'Mode' panel

The ***Mode*** panel is *engine-specific*. Some of the process modes available for the static engine are not available for the kinematic and stop-and-go engines (and vice versa).
As the panel name implies, here the user will select the desired process mode, i.e. the specific technique used by the engine in vector and/or trajectory processing.

8.1.1 Process modes for the Static engine

The following options are available :

- ***AUTO*** — Program selects an optimal processing mode automatically.
- ***L1&L2*** — Processing dual frequency measurements (recommended for shorter baselines). L1 and L2 observables will treated by the engine as independent data sets (i.e. the engine will formulate no mixed combinations from L1 and L2 observables).
- ***L1 Only*** — Processing single frequency measurements (this is 'standard' when using single frequency receivers).
- ***L2 Only*** — Processing L2 measurements only (this is mainly used for research purposes).

---

[10]) Note that *engine properties for a specific Occupation* (see 7.7.11) are absolutely different from *engine properties for a specific Solution*

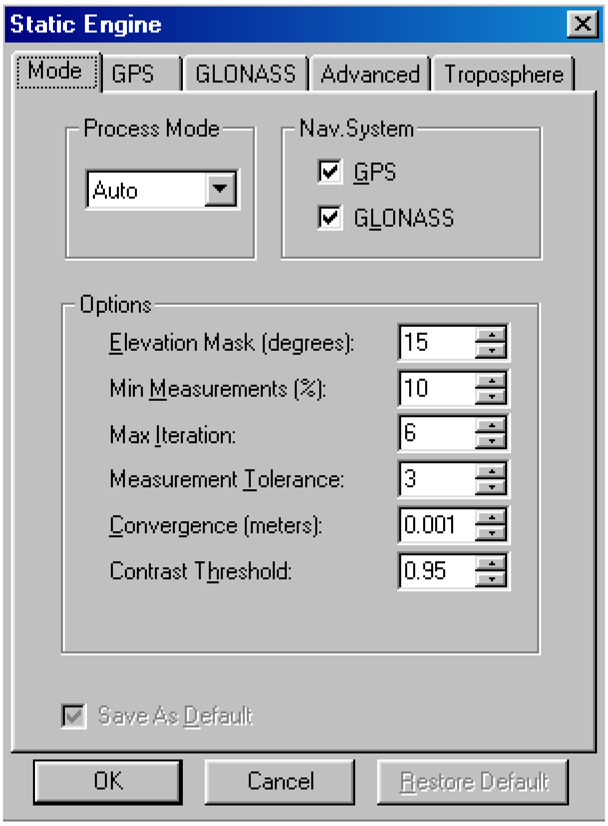


Figure 8-1

- ***L1c*** — Processing dual frequency measurements collected on longer baselines. An ionosphere-free combination is formulated and processed but integer biases are not fixed. This is also known as a float solution.
- ***L1-L2*** — Processing a wide-lane combination.
- ***L1+L2*** — Processing a narrow-lane combination (this is mainly used for research purposes).
- ***L1&L2c*** — The most powerful processing including both integer ambiguity resolution and the formulation of an ionosphere-free combination. This is often considered the principal technique for processing dual frequency measurements.
- ***VLBL*** – Processing very long baselines
- ***Wide Lane*** – This can be considered as "a modified ***L1-L2*** mode". There are scenarios where the residual ionosphere is too large for either L1&L2 or L1&L2c to provide fixed solutions and yet the raw data are considered good enough to allow correct estimates of (L1-L2) ambiguities.
  The *wide lane* mode is based on the following:
  1) $N^{Lc}[i] = N^{L1}[i] + a \cdot N^{L2}[i]$
     $N^{L1\text{-}L2}[i] = N^{L1}[i] - N^{L2}[i]$
     $N^{Lc}[I] = N^{L1}[i] + \boldsymbol{\alpha} \cdot (N^{L1}[i] - N^{L1\text{-}L2}[i])$, (*)
     where
     $N^{L1}[i]$ - integer ambiguities from L1 equations
     $N^{L2}[i]$ - integer ambiguities from L2 equations
     $N^{L1\text{-}L2}[i]$ - integer ambiguities from (L1-L2) equations
     $N^{Lc}[I]$ –*float* ambiguities from the ionosphere-free combination equations
     α - factor depending on the ratio **freq(L1)/freq(L2)**.
  2) Assuming $N^{L1\text{-}L2}[i]$ ambiguities can be computed correctly using the standard ***L1-L2*** technique .

3) Formulate and solve the set of the ionosphere-free combination equations, estimate the variance-covariance matrix and then use this matrix to create the corresponding quadratic form in _float_ parameters $\mathbf{N^{Lc}[i]}$.
4) By using the assumption that the ambiguities $\mathbf{N^{L1\text{-}L2}[i]}$ are computed correctly and taking into account the relationship (*), we can also treat the above mentioned quadratic form as a function of the _integer_ parameters $\mathbf{N^{L1}[i]}$.
5) Finally, we will minimize this quadratic form (in the integer parameters $\mathbf{N^{L1}[i]}$) on an integer grid thus obtaining the resulting fixed L1 and L2 ambiguities.

- ***Code Only*** - this is based on using pseudo-ranges only

WARNING: The user will typically obtain some 0.5 - 1 ppm accuracies when processing very long vectors with the use of 'VLBL'. Since this mode is based on a trivial triple-difference technique, it cannot be recommended to those seeking centimeter-level accuracies on several hundred kilometer (or longer) baselines. When using triple differences, critical measurement errors are not properly modeled (they are not eliminated either!), which will adversely affect the final VLBL solution's accuracy.

When selecting AUTO, the user should keep in mind the following 'in-built' criterion PROCESS uses:
- if a vector processed is shorter than 10 km, AUTO is equivalent to L1&L2;
- for vectors falling into the 10 km - 30 km bracket, AUTO is equivalent to L1&L2c;
- for the 30 km to 400 km bracket, AUTO coincides with WideLane;
- finally, if a vector is longer than 400 km, AUTO is equivalent to VLBL

Nav. System — This allows the desired constellation to be chosen (GPS, GLONASS, or both).
Elevation Mask — Specifies an elevation cut-off angle (in degrees) for satellites used in data processing.
Min Measurements — Specifies the minimum percentage of measurements required for the corresponding observables to be used in the course of processing.
Max Iteration — Maximum number of iterations allowed for the process to converge.
Measurement Tolerance — Specifies an outlier rejection threshold (in units of “sigma”).
Convergence — Specifies a process convergence criterion (in meters).
Contrast Threshold — Specifies a contrast test ratio, which is used for ambiguity resolution.

8.1.2 Process modes for the Kinematic and Stop-and-go engines

The following is a list of the process modes allowed for the kinematic and stop-and-go engines.
- ***L1 Only***
- ***L1&L2***
- ***L1&L2c***
- ***L1-L2***
- ***Wide Lane***
- ***Code Only***

Default is ***L1&L2c.***

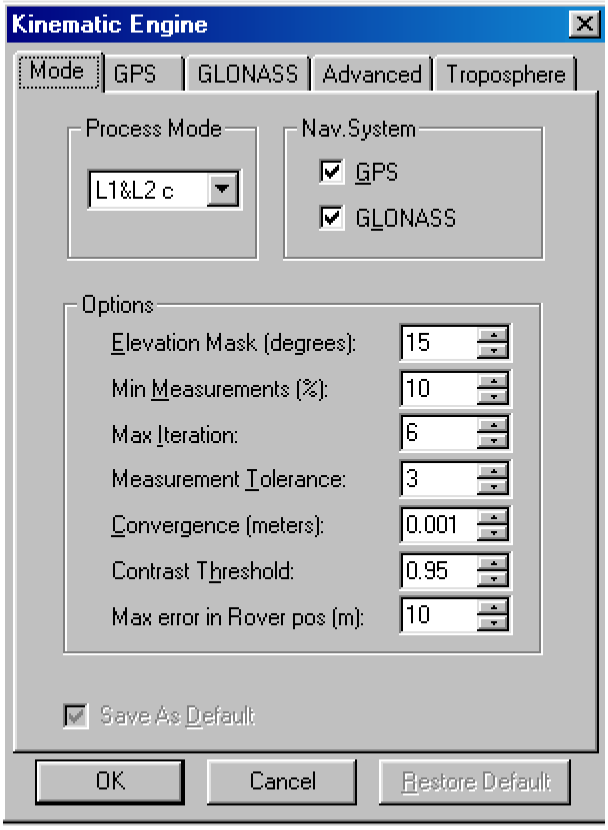


Figure 8-2

Note the option ***Max error in Rover pos (m)*** at the bottom of the panel (see Figure 8-2), which is not available for static mode. If this option is set to ***r*** meters, the corresponding fan reports will not include any trajectory points for which the estimated rms position errors exceed the specified threshold equal to ***r*** meters. The default threshold is set to 10 meters.

8.2 'GPS' panel

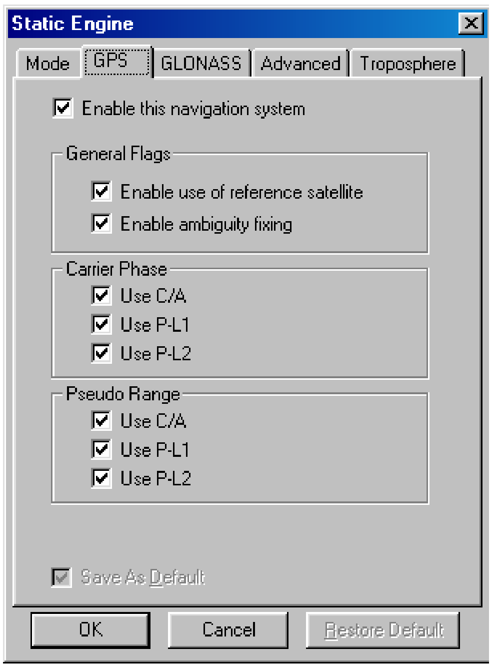


Figure 8-3

Enable this navigation system — This system will be used in the solution. Note that this field duplicates the **Nav.System** field in the ***Mode*** panel
Enable use of reference SV — If checked, only one satellites is used as a reference when formulating double differences.
Enable ambiguity fixing — If checked, the engine is forced to search for a fixed ambiguity solution.
The ***Carrier Phase*** checkbox triplet:

Use C/A — Indicates that this channel's carrier phase measurements will be used by the engine (L1-frequency & coarse acquisition code).
Use P-L1 — Indicates that this channel's carrier phase measurements will be used by the engine (L1-frequency & precise code).
Use P-L2 — Indicates that this channel's carrier phase measurements will be used by the engine (L2-frequency).

The ***Pseudo Range*** checkbox triplet:

Use C/A — Indicates that this channel's code phase measurements will be used by the engine (L1-frequency & coarse acquisition code).
Use P-L1 — Indicates that this channel's code phase measurements will be used by the engine (L1-frequency & precise code).
Use P-L2 — Indicates that this channel's code phase measurements will be used by the engine (L2-frequency & precise code).

8.3 'GLONASS' panel

The **GLONASS** panel is similar to that of **GPS**.

8.4 'Advanced' panel

8.4.1 Settings available for the Static engine

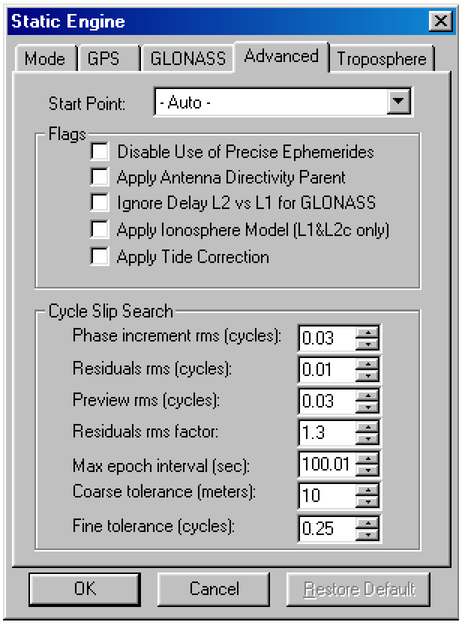


Figure 8-4

The **Start Point** listbox allows the user to specify the 'seed' point that will be used as a reference position when computing vectors. Note however that it is often impossible to compute all vectors available in the given solution by using a single 'seed' point (no matter whether this seed point is explicitly selected by the user or implicitly by Pinnacle). For example, when processing vectors[11] for a group of isolated subnets (without common points) that were measured one by one (not concurrently), Pinnacle will have to implicitly use different 'seed' points for different subnets. Therefore the user should bear in mind that the *Start* point thus selected will not necessarily 'serve' all the vectors processed.

Question: how will Pinnacle set the *Start* point if **AUTO** is selected?
Consider the two most common scenarios.
Scenario A: All points have only navigational coordinates (i.e.none of the points has control attached to them).
Scenario B: Some of the points shown in the 'Start point' listbox have control[12] attached to them (such points will be marks with the "*(fixed)*" tag).

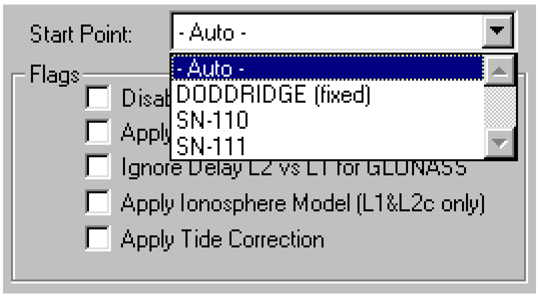


Figure 8-5

Scenario A:

If the user selects AUTO and there are no control points in the list, Pinnacle will first search for the point(s) with the maximum total occupation time and then, if more than one such point is found, select the one having the minimum rms position error.

Scenario B:

If the user selects AUTO and there are points with attached control in the list, Pinnacle will use the control point with the minimum rms position error as the *Start* point.

Note that if the user selects a specific point to be used as the *Start* point but this point turns out to be "*isolated*" from some other (vector end) points in the Solution, Pinnacle will have to implicitly choose additional *seed* points while computing the selected vectors. Also note that such 'additional' seed points will be selected using the same criteria as described above for AUTO.

8.4.1.1 *Description of* **'Flags'**

Disable Use of Precise Ephemerides – if this option is on, only broadcast orbits will be used in vector computation.

Apply Antenna Directivity Pattern - if this option is on, the static engine will apply the antenna directivity pattern corrections to the carrier phase observables. These corrections are borrowed from the well-known *antenna files* developed by Dr.Mader.

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[11]) it is assumed that the vectors reside in the same solution

[12]) assuming the control was attached using a Control Data List

For detailed information on the antenna directivity pattern, L1 vs.L2 phase center offsets and other parameters for a specific antenna type, click on the ***Device Editor*** button.

Ignore L2 vs L1 Delay for GLONASS – if this option is on when processing GNSS receivers' raw data, the engine will model *different* delays for GLONASS code phase measurements on L1 and L2, respectively. This option can normally be used (i.e. the L1 vs. L2 delays can be ignored) only if the same receiver model was used to collect raw data on the base and rover sides.

Apply Iononsphere Model (L1&L2c) – This option is intended specifically for ***L1&L2c***. If this option is on, the engine will *model* the differential ionosphere to facilitate 'independent' L1 and L2 ambiguity resolution at the initial process stage (***L1&L2***). This option is recommended when processing baselines 100+ km.
Note. Differential ionosphere will be modeled as a first-order Gauss-Markov with the correllation time $\tau=3$ minutes and the amplitude $\alpha=3 * 10^{-6} *$ ***baseline length*** meters.

Apply Tide Correction – if this option is on, the engine will use the necessary corrections to account for ocean-tide effects at the Base and Rover. This option is normally recommended for baselines > 100 km.

8.4.1.2 *Description of the* Cycle Slip Search *parameters*

If the user decides to update the default settings, care should be exercised to ensure that the new settings are practicable. These parameters are as follows:
Phase increment rms (cycles) — is the maximum acceptable carrier phase increment RMS error.
Residuals rms (cycles) — is the maximum acceptable (normalized) sum of squared residuals.
Preview rms (cycles) — is the maximum acceptable (normalized) sum of squared carrier phase increments as applicable to static occupations.
Residuals rms factor — this parameter (which must be >1) specifies a threshold 'post-static increase' for the sum of squared residuals.
Max epoch interval (sec) — specifies the maximum acceptable gap between adjacent measurement times when checking for phase measurement consistency.
Coarse tolerance (meters) — is the maximum acceptable discrepancy between code phases at adjacent measurement epochs. This is used when searching for large phase slips caused by loss of lock in the carrier phase loop.
Fine tolerance (cycles) — is the maximum acceptable carrier phase discrepancy. If the fractional part of the phase exceeds this value, the measurement will be omitted.

8.4.2 Settings available for the Kinematic engine

Note that the options ***Apply Iononsphere Model (L1&L2c)*** and ***Apply Tide Correction*** are unavailable for the Kinematic engine. The other options are identical to their counterparts existing for the Static engine (see 8.4.1.1).

8.5 'Troposphere' panel

Pinnacle uses the Goad & Goodman troposphere model.

8.5.1 Troposphere settings for the Static engine

Don't Use Troposphere Model – do not enable this option unless it is known in advance that the differential troposphere is negligible for the given baseline (e.g., if both the base and rover have nearly identical heights above the sea level and the baseline is relatively short).

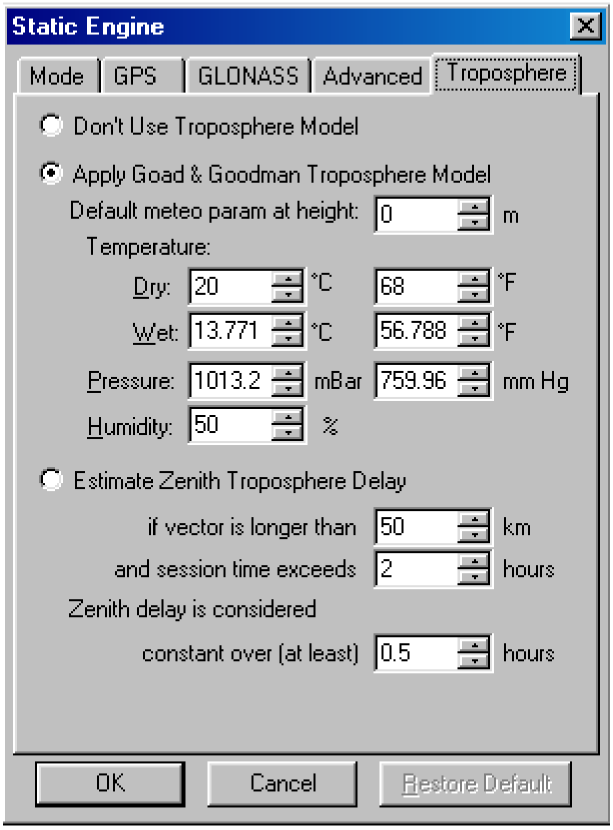

Figure 8-6

Apply Goad & Goodman Troposphere Model – if this radio button is on, Pinnacle will use the troposphere parameters as specified in the corresponding spinboxes. Note that these parameters will correspond to the base station.

Estimate Zenith Troposphere Delay – if this option is on, Pinnacle will estimate the zenith troposhere delay based on the available raw data measurements and the above specified troposphere parameters (wet/dry temperature, pressure, humidity, etc.)
The zenith troposphere will be estimated by using the *Goad & Goodman* model.
In short, the rationale for the technique is this:
It is assumed that the actual troposphere can be adequately described by scaling the a priori (computed) troposphere by a certain unknown factor. This unknown factor needs to be estimated by using the collected raw data measurements.
In fact, Pinnacle will estimate the zenith troposphere as a step-wise function, not a single scalar. The length of the 'step' is defined by the user.
It makes sense therefore to model zenith troposphere only if the baseline is larger than 100 km and the session is a few hours long.

8.5.2 Troposphere settings for the Kinematic engine

The ***'Troposphere'*** panels for the Static and Kinematic engine are identical except for the ***Estimate Zenith Troposphere Delay*** option, which is not available in kinematics.

9 Run Process

Process can be invoked in the following ways:

- If it is necessary to calculate the Vectors, Fans, Vectors/Fans included in the given ***Solution***, select the ***Run Process*** command from the ***Solution*** menu or click on the 'Process' button in the toolbar at the top of Pinnacle's main window.
- If it is necessary to process only those Vectors that have not yet been processed or have been updated since they were last processed, then press the ***Make*** button in the toolbar.
- If it is necessary to process a single Vector — select the ***Process Vector*** option from the ***Vector*** menu.

All of the commands invoking ***Process*** form a *processing task list,* which is stored in the ***Process Queue***. This queue is shown in the ***Process*** window.

Tasks are executed sequentially according to the queue order.
Task execution may be paused or cancelled. Any task can be deleted from the queue if required.
Every task is assigned its *current status*, which is represented as a special symbol preceding the corresponding 'task line' in the window. The following task status signs are used:

Table 2

	Message
	Warning
	Error (e.g. if task is broken by *User*)
	Fatal Error
	Waiting
	Process
	Fault
	Success
	AmbFloat – float ambiguities are being estimated
	AmbFixed – fixed ambiguities are being estimated

Tasks are managed through the **Process window's** toolbar with the help of the following buttons:

Run Process — Pressing this button will change the task status from ***Ready*** or ***Processed*** to ***Waiting***.

Terminate Process — Pressing this button will stop the execution of the current task and change the status of all the remaining tasks from ***Waiting*** to ***Ready*** (in other words, this will halt ***Process*** completely).

Pause Process / Resume Process — This is to stop/continue the execution of the current task.

Status Window — This is used to activate the ***Engine Status Window***.

Delete — Deletes selected task from the queue.

Options — Activates the ***Process Options*** dialog box (Once the ***Process Options*** dialog box is activated, computation will stop. To resume vector/trajectory computation, press ***OK*** or ***Cancel***).

9.1 Process Window

While processing vectors/trajectories Pinnacle will display various interim process information in the ***Process Window***.

9.1.1 Process Window for static Solutions

Figure 9-1 shows an example of the 'Process' window derived for three processed vectors:

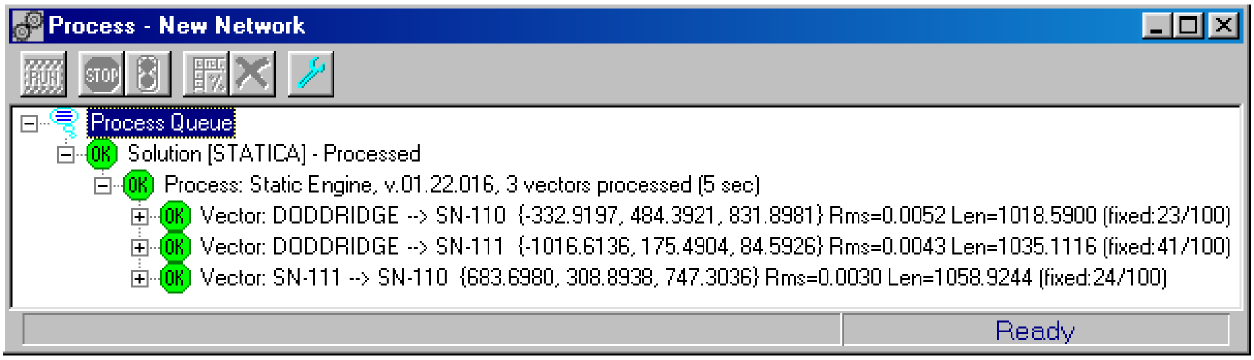

Figure 9-1

1) Solution [STATICA] - Processed - means that the solution named STATICA has been successfully processed,

2) Process: Static Engine, v.01.22.016, 3 vectors processed (5 sec) - indicates the type and version of the engine used, total number of the processed vectors and the corresponding computation time in seconds.

Below the user will see information on individual vectors:

3) Vector: DODDRIDGE --> SN-110 {-332.9197, 484.3921, 831.8981} Rms=0.0052 Len=1018.5900 (fixed:23/100) -

- OK means that the solution is ***fixed*** (all ambiguities have been fixed to integers) ,
- means that the obtained solution is either ***partial*** (some of the estimated ambiguties are integers while others are floats) or ***float*** (all estimated ambiguities are float numbers)
- names of the end-points of the computed vector
- components of the computed vector in WGS84
- square root of the trace of the variance-covariance matrix (a.k.a. "rms position error"); this error is measured in meters
- length of the computed vector
- solution type (*fixed* in this example), total number of ambiguities used when computing the vector (*23* in this example), minimum contrast ratio obtained [in %] (*100* percent in this example).

After the vector node is expanded, the user will see:

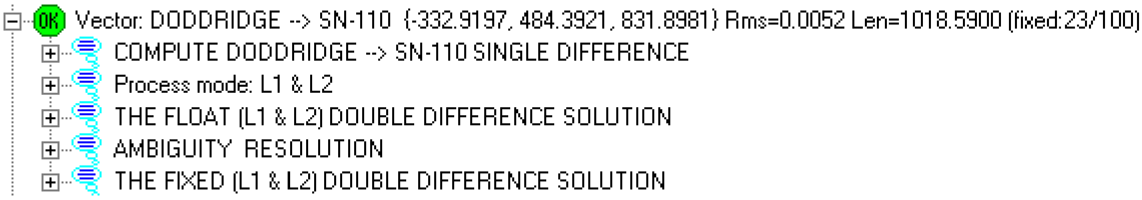

Figure 9-2

Each of the process stages will have its own node ('*processing single differences'*, '*obtaining a float solution'*, '*resolving ambiguities'*, '*obtaining a fixed solution'*, etc.)
If a vector is recomputed[13] and its updated processing coordinates differ from the previous ones[14] by more than **1 meter + 10 ppm,** then the warning message 

will be reported together with the information shown in Figure 9-2 .

9.1.1.1 Compute Single Differences

If the ***COMPUTE SINGLE DIFFERENCE*** node is expanded, the user will see the following information:

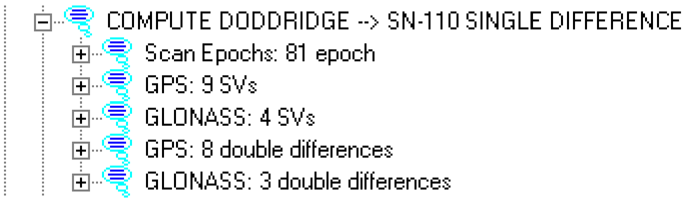

Figure 9-3

1) Total number of epochs available for the given vector as well as information about detected loss-of-lock events (time and size of each detected cycle slip, identification of the satellite and the channel where the slip occurred):

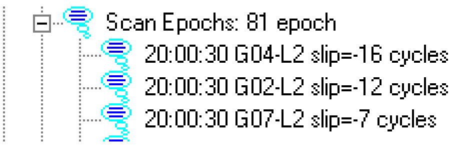

Figure 9-4

2) Total number of GPS and GLONASS satellites used, their PRN's and orbit slot numbers, observation times, amount of epochs available for each observed satellite, elevation angle shots at the beginning and the end of the observation interval:

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[13]) with updated process settings

[14]) the previous processing coordinates have been stored to the project database

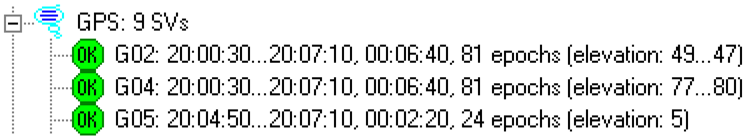


Figure 9-5

3) total number of double-differenced GPS and GLONASS carrier phase observables together with the related information on SVs' PRN and orbit slot numbers, observation times, amount of available epochs:

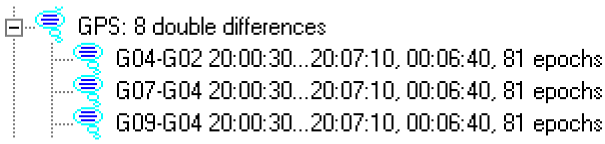


Figure 9-6

9.1.1.2 Process mode

Under the ***Process mode*** node the user will find complete information on the process settings used in vector computation:

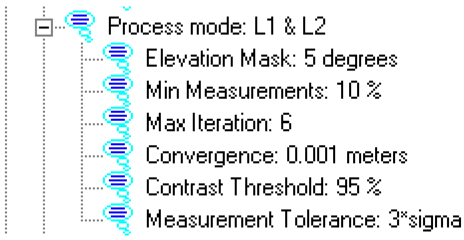


Figure 9-7

9.1.1.3 Float Double-Differenced Solution

If the node ***FLOAT DOUBLE DIFFERENCE SOLUTION*** is expanded, the user will see various information on the *float double-differenced solution*:

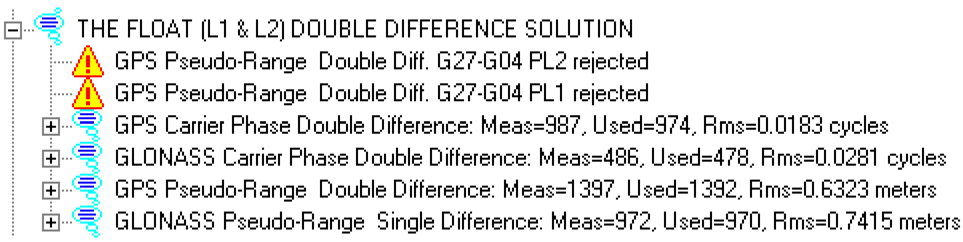


Figure 9-8

1) What particular data for which particular satellites were rejected when computing the float DD solution.
2) Total number of carrier phase measurements and the estimated root-mean-squared DD carrier phase residual error for GPS satellites.
3) Total number of carrier phase measurements and the estimated root-mean-squared DD carrier phase residual error for GLONASS satellites.

4) Total number of the code phase measurements and the estimated root-mean-squared DD code phase residual error for GPS satellites.
5) Total number of the code phase measurements and the estimated root-mean-squared DD code phase residual error for GLONASS satellites.

Moreover, not only can the user get the *averaged* residual errors for all GPS or GLONASS satellites used but also specific estimates for each specific DD observable:

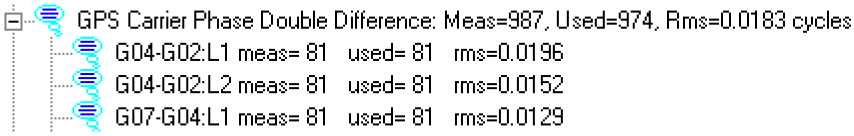


Figure 9-9

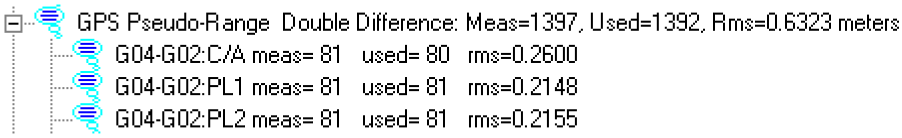


Figure 9-10

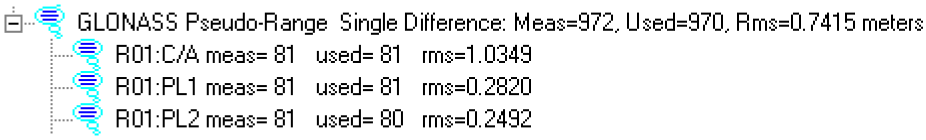


Figure 9-11

9.1.1.4 Ambiguity Resolution

If the node ***AMBIGUITY RESOLUTION*** is expanded, the user will see detailed information on the estimated ambiguities.

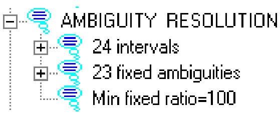


Figure 9-12

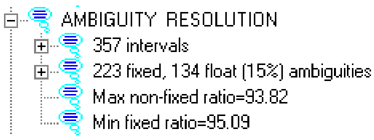


Figure 9-13

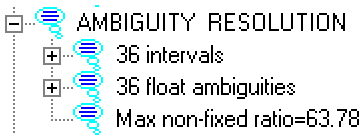


Figure 9-14

Figures 9-12, 9-13, 9-14 correspond to the following three scenarios:

1) *Ideal* case: all of the ambiguities are fixed and the contrast ratio reaches its maximum (100%).
2) *General* case: some of the ambiguities are fixed but the rest are floats.
3) *Worst* case: Pinnacle fails to fix any of the ambiguities (all ambiguities are floats).

***Note**. After processing mixed GPS&GLONASS raw data measurements with the option '**Ignore L2 vs L1 Delay for GLONASS**' set to 'off' (see 8.4.1.1), the ambiguity list will include an additional float bias*[15]*. This is due to the systematic offset existing between L1 and L2 code phase measurements in GLONASS (*Figure 9-15*). This is why the number of ambiguity intervals may be greater than the number of fixed ambiguities* *<u>even in the ideal case</u>* *(as seen from* Figures 9-12…9-14)

Below is the description of the parameters the user will find under the 'Ambiguity Resolution' node:

- ***'N' intervals*** means that the total number of *ambiguity intervals* used to compute the vector was equal to ***N***.
- ***'N1' fixed, 'N2' float ('N3'%) ambiguities*** means that
  - o N1 ambiguities are fixed to integers,
  - o N2 ambiguities are left floats and
  - o Pinnacle has failed to fix ambiguities for ***N3*** percent of the double differenced carrier phase observables available for the given vector.
- ***Min fixed ratio*** means the minimum of the 'successful' contrast ratio values (in percentage) achieved while iteratively fixing the ambiguity vector. Note that the *minimum fixed ratio* will always be greater than the *contrast threshold* mask (multiplied by 100) specified in the 'Mode' panel of the 'Engine properties' dialog window (see Figure 8-1 in 8.1.1).
- ***Max non-fixed ratio*** means the maximum of the 'unsuccessful' contrast ratio values (in percentage) achieved while iteratively fixing the ambiguity vector. Note that the *maximum non-fixed ratio* will always be lower than the *contrast threshold* mask (multiplied by 100) as specified in the '*Mode'* panel of the '*Engine properties*' dialog window.

9.1.1.4.1 Expanding the ***'... intervals'*** node

If the node ***'... intervals'*** is expanded, the user will see an *ambiguity interval list*.

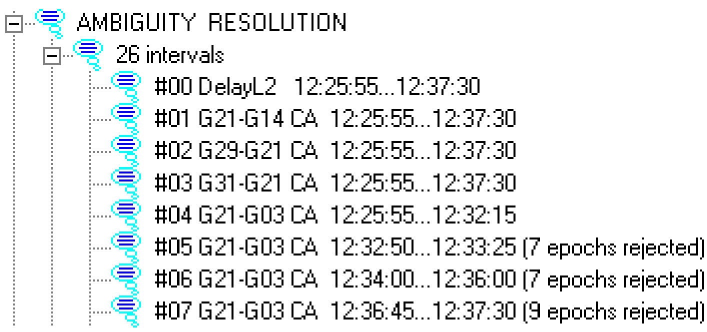


Figure 9-15

Each line in this list will include the following information[16]:

- ambiguity interval number, e.g. #03
- satellites associated with this ambiguity (or in other words with this DD carrier phase observable), e.g., G31-G03

---

[15]) *historically, this bias is referred to as 'ambiguity' also*

[16]) *it is true with one reservation (see the blue-bordered note in 9.1.1.4)*

- ambiguity type (CA, L1, L2, L1-L2, L1+L2, etc.)
- start and end times of the ambiguity interval, e.g. 12:25:55…12:32:15
- time gap (number of epochs rejected by the engine) between the current and previous ambiguity intervals. For example, the notation '*(7 epochs rejected)'* in line #05 means that there is a 35-second gap (seven rejected epochs) between ambiguity interval #04 and ambiguity interval #05.

9.1.1.4.2 Expanding the '***...fixed …float ambiguities'*** node.

If the node ***'...fixed …float ambiguities'*** is expanded, the user will see detailed information on each individual *ambiguity*.

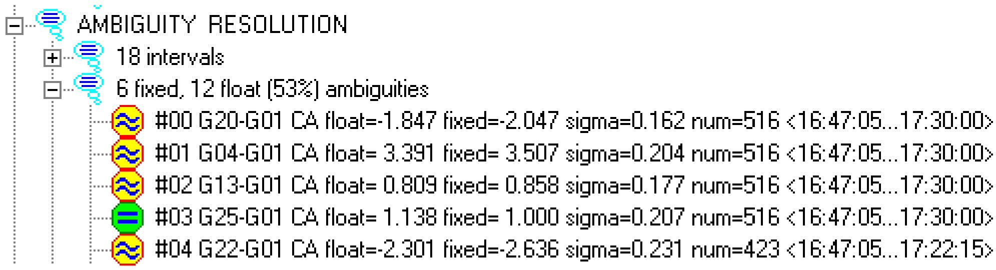


Figure 9-16

Ambiguities that are fixed to integers will be marked with . Ambiguities that are fixed to floats will be marked with .

Each line in the ambiguity list will comprise the following information:

- ambiguity number
- satellites associated with this ambiguity
- ambiguity type (C/A, L1, etc.)
- (intermediate) float estimate computed at the float solution stage, e.g., ***…float=3.391 …***
- (final) fixed estimate computed at the fixed solution stage, e.g., ***…fixed=1.000…*** (*engine* has succeeded in fixing this ambiguity to an integer) or ***…fixed=3.507…***(*engine* has failed to fix this ambiguity to an integer)
- rms error of the intermediate float estimate if the ambiguity is eventually fixed to an integer, and the rms error of the final float estimate otherwise.
- total number of epochs related to the ambiguity.
- ambiguity lifetime (start and end times)

9.1.1.5 Fixed Double-Differenced Solution

Structurally the nodes ***FIXED DOUBLE DIFFERENCE SOLUTION*** and ***FLOAT DOUBLE DIFFERENCE SOLUTION*** are identical. For a detailed description of the parameters used in the *fixed double differenced solution* section of the Process Window tree, refer to 9.1.1.3.

9.1.2 Process Window for a STOP&GO Solution

Figure 9-17 shows the *process window* tree for a processed stop-and-go solution comprising four static vectors and one fan.

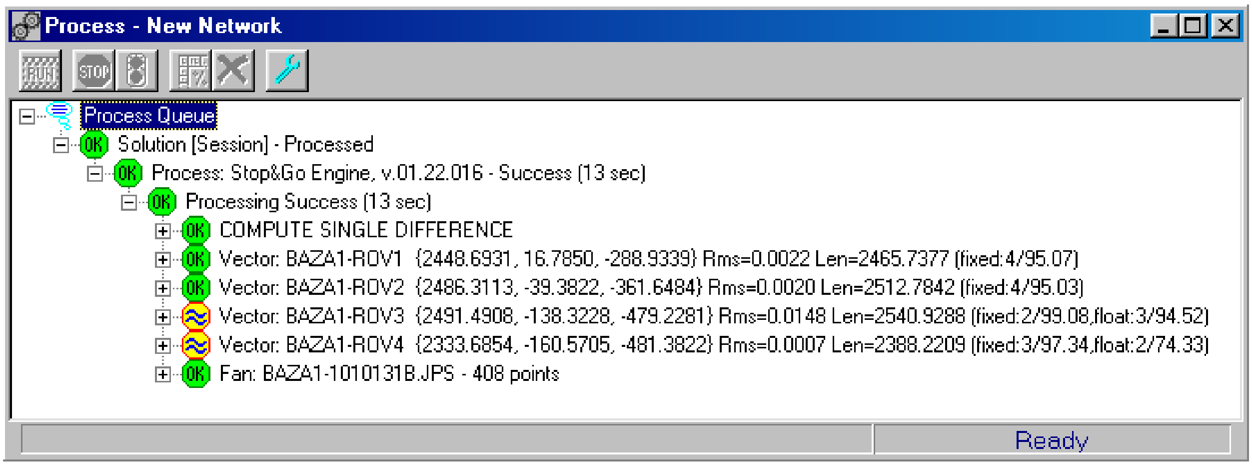


Figure 9-17

There is one further essential difference between how vectors (if measured in 'stop-and-go' mode) are processed by the static and stop-and-go engines.
When processing vectors with short occupation times, the stop-and-go engine will use not only all of the static occupations available for the vector but also some of the adjacent kinematic occupations (if necessary). That is why the kinematic engine will notify the user about what specific part of the entire stop-ang-go trajectory has been used to compute the given vector. If we could expand the node 'Vector BAZA1-ROV1' in the tree shown in Figure 9-17, we would see the line

indicating that
- the vector has been computed using the *trajectory section* starting at 21:59:52 and ending at 22:08:55 and that
- this section includes 544 epochs.

In fact, the static occupation alone includes only 62 epochs for this vector[17]. If the engine had used exclusively the static occupation's raw data, it would probably have failed to get a good fixed solution for the vector (Figure 9-18)

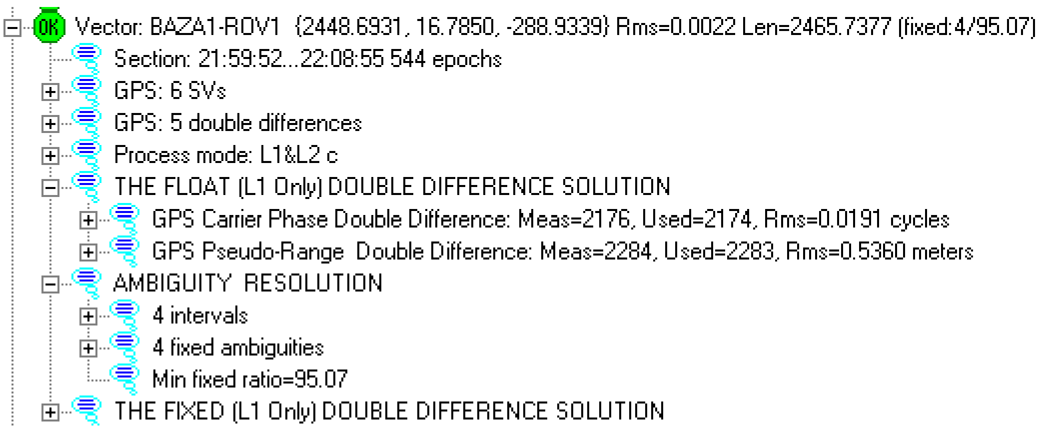


Figure 9-18

---

[17]) this information is not explicitly shown in Figure 9-17 so that the user will have to believe us on our word :-

Before the stop-and-go engine starts processing a fan, it will divide the entire trajectory into sections. Each section will be processed independently. Figure 9-19 illustrates how a typical processed fan will be presented in the process window tree:

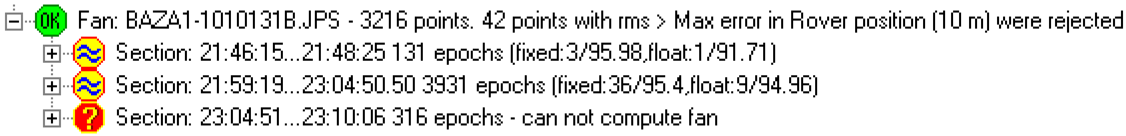


Figure 9-19

Note that the stop-and-go engine will notify the user how many trajectory points have been filtered out as outliers (according to the rms error mask specified in the 'Mode' panel of the 'Process properties' window (see Figure 8-2).
Each section, if expanded, will look as shown in Figure 9-20:

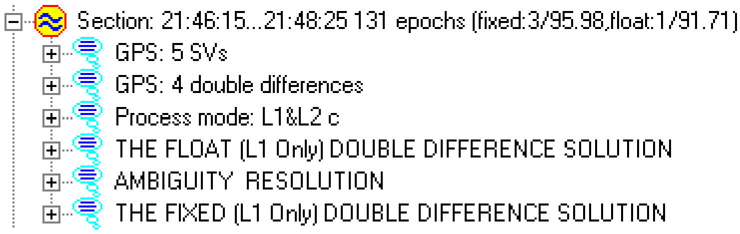


Figure 9-20

9.1.3 Process Window for a Kinematic solution

Figure 9-21 shows how the process window tree will look when processing a fan from a kinematic solution.

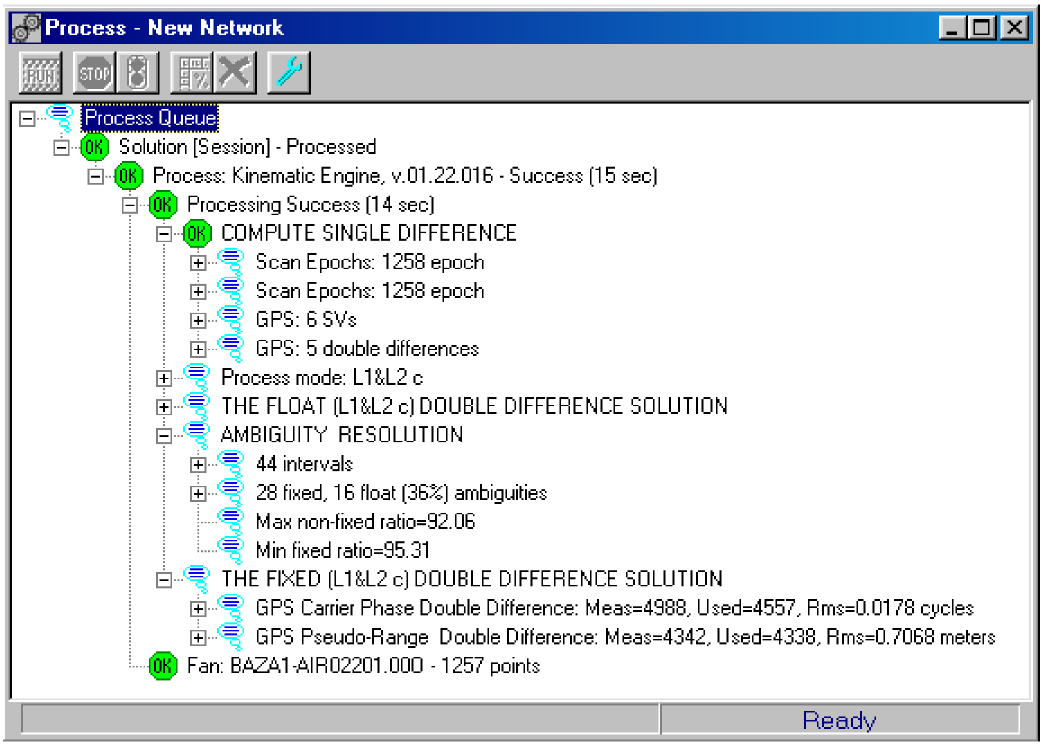


Figure 9-21

Note that the kinematic engine (unlike the stop-and-go one) will not use or display any information on specific *'trajectory sections'*.

10 Raw Data Graph

10.1 Introduction

Along with the tabular tool for browsing raw data, Pinnacle also offers a powerful means for graphical presentation of navigational parameters, receiver observables and related information for up to four particular occupations at a time. This graphical tool, which is called ***Raw Data Graph***, allows the user to view not only any of the 'basic' GPS/GLONASS observables but also various algebraic combinations of them.

To launch ***Raw Data Graph***, the user will

- Go to the *Raw Data Session* panel.
- Check the desired occupation(s) (note that up to four occupations may be selected at a time)
- Right-click on any of the selected occupations. From the pull-down menu, select the *'Raw Data Graph'* option.

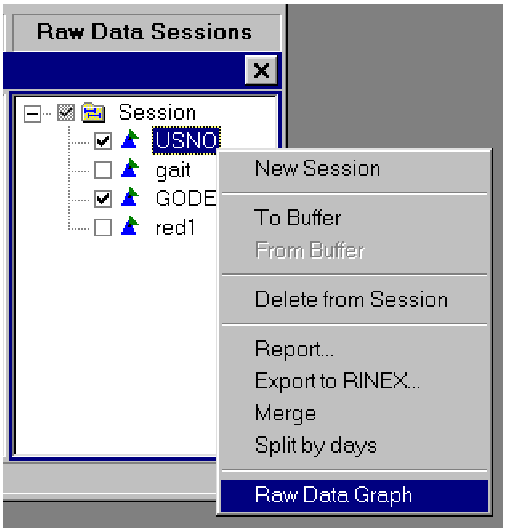


Figure 10-1

- The *'Function Editor'* dialog window will appear.

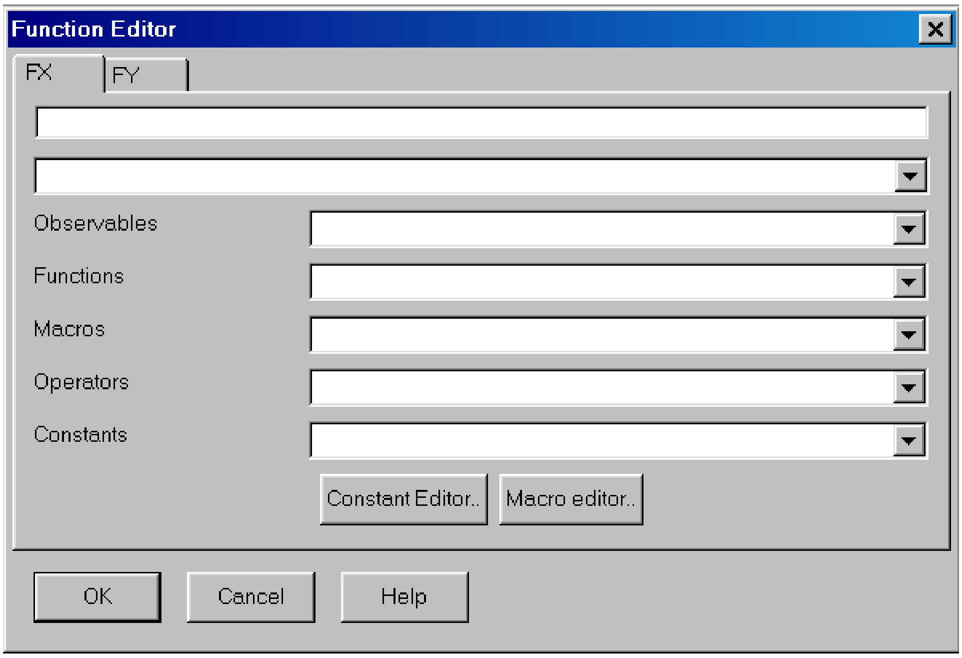


Figure 10-2

This dialog window has two tabs.
The FX tab is used to specify the data presented on the X-axis.
The FY tab serves the same purpose but for the Y-axis.

In the topmost edit box, the user must define the required two "expressions" governing the X-axis and Y-axis, respectively. These expressions may be built up from the pre-defined ***observable*** *functions*, *(algebraic)* ***functions***, ***macros***, ***operators*** and ***constants*** stored in the *Function Editor's* database and available via the corresponding list boxes.

For user convenience, the second topmost edit box serves as a *'History'* list box. This may store up to 30 last used expressions.

Once both FX-expression and FY-expression are specified, the *'Function Parameters'* dialog window will appear. In the next section, we will see how to use 'observable functions' for building various raw data plots. For macros, they are used in the same manner.

Although there are no formal limitations on how FX- and FY-expressions are built, it is strongly recommended to assign one of the axes as either *'rectime'* or *'curepoch'*. Otherwise the user will risk obtaining a complicated (FX, FY) "manifold", not a regular (unambiguous) function FY = FUNCTION(FX). Also, if neither of FX, FY describes time explicitly, the user may not be able to find out what specific time a given point on the (FX, FY)-plot is referenced to.

Lastly, if some of the arguments in the FX-, FY-expressions are not found in the raw data, a *'Function is undefined'* error will be reported.

10.2 'Function Parameters' dialog window

Before listing here all the observable functions and macros available in *Raw Data Graph*, let us have a closer look at one of them, ***carrier_phase(occupation, epochnum, satellite, channel)***, which describes undifferenced carrier phase observables. This example a good demonstration of how to handle all the other observable functions and macros.

First, choose an appropriate FX-expression. In the '*Function Editor*', open the FX-tab and select "*rectime(oparam1,curepoch(oparam1))*" from the '*Observables*' list box.

Next, choose the right FY-expression from the analogous list box in the FY-tab. It should be the "*carrier_phase(oparam1,curepoch(oparam1),sparam1,cparam1)*" function. Press 'OK'. The *'Function Parameters'* dialog window will appear. This dialog window has three tabs. These tabs are as follows:

10.2.1 'Function Parameters' tab

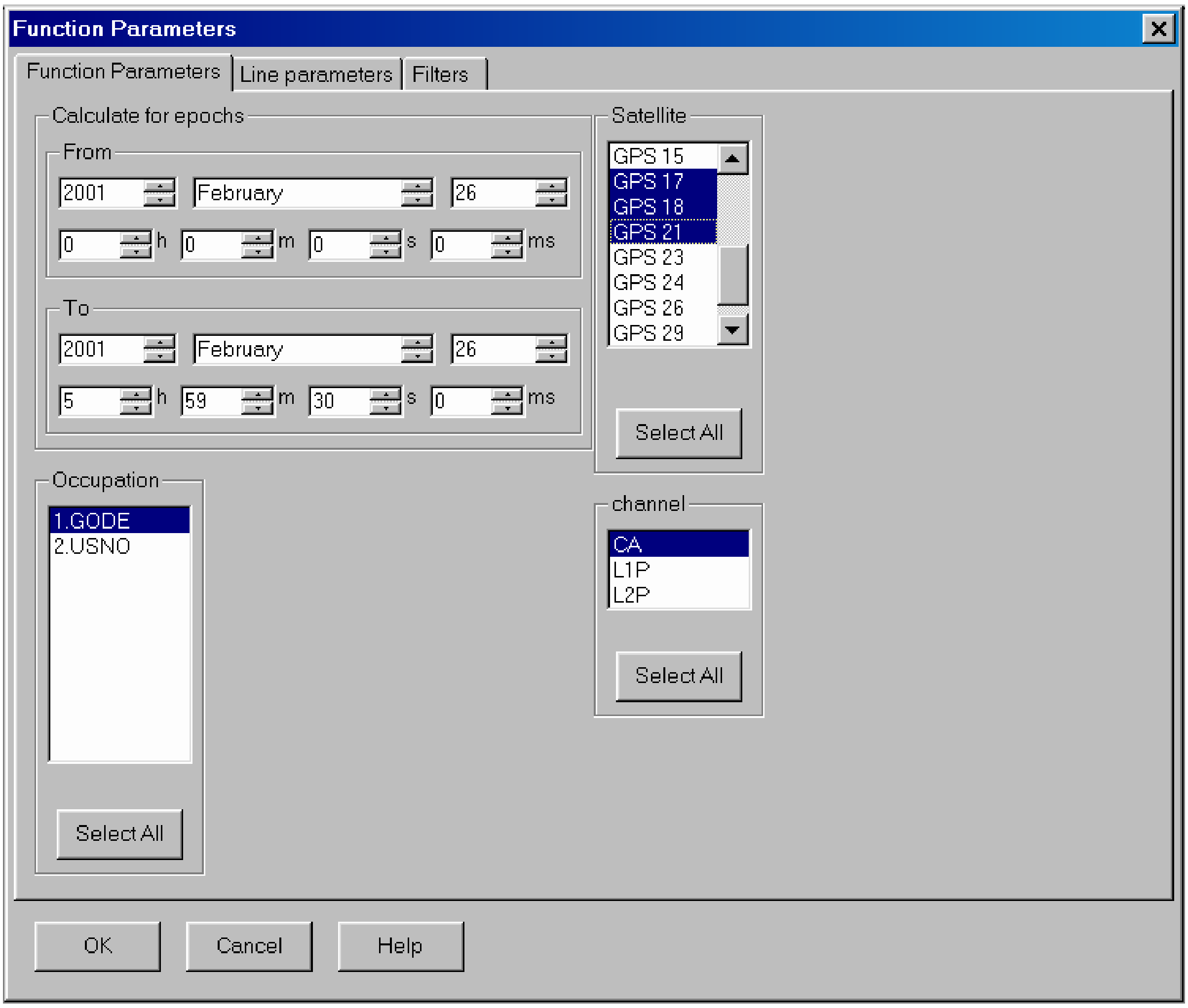


Figure 10-3

In this tab, should be entered all the necessary arguments. This procedure is very straightforward (see Figure 10-3):

- "*To specify occupation(s)*" means, first, to highlight in the '*Occupation*' list box all the desired occupations and, second, specify the start and end times via the 'Calculate for Epochs" group of spinboxes.
- *"To specify satellite(s)"* means to highlight in the *'Satellite'* list box all the desired satellites.
- *"To specify channel(s)"* means to highlight in the *Channel* listbox the desired channel slots.

Note that it is not necessary to specify the *epochnum* argument explicitly - the program will implicitly use the *curepoch (occupation)* and *fstepoch(occupation)* observable functions when handling the time argument.

10.2.2 'Line Parameters' Tab

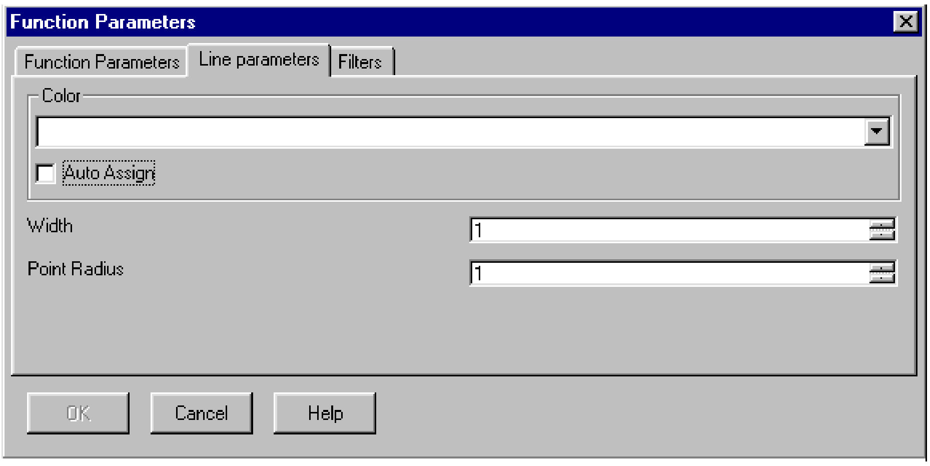


Figure 10-4

The '*Line Parameters*' tab allows the user to update the colors and change the line width and point size on the plots. There is however one limitation on changing colors: if the *'Auto Assign'* checkbox is checked, it will not be possible for the user to assign colors on his own since the program will select them automatically.

10.2.3 'Filters' tab

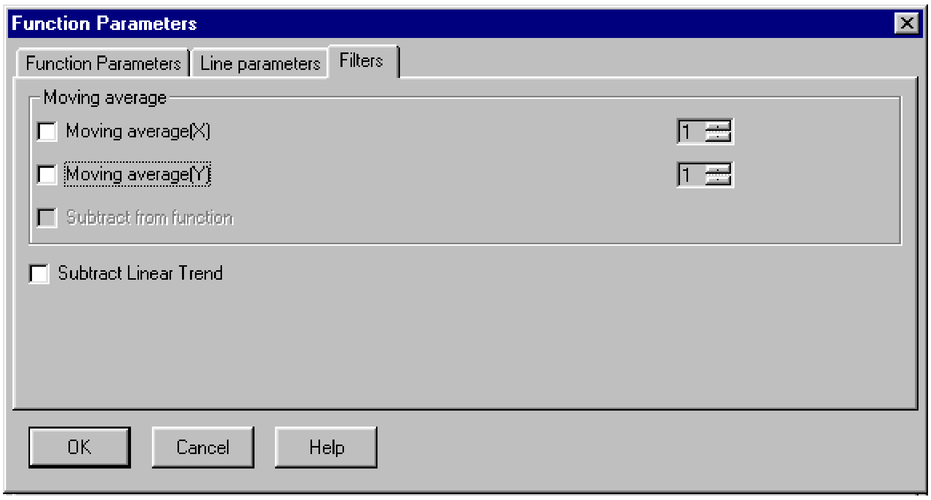


Figure 10-5

- When the *'Moving Average (…)'* checkboxes are checked, the program displays $\sum_{i=-k}^{k} X(t_{n+i})/(2k+1), \sum_{i=-k}^{k} Y(t_{n+i})/(2k+1)$ for $X(t_n), Y(t_n)$, respectively.
  Here t_n designates the n-th epoch of the given occupation. To specify the *length* of the moving average filter (i.e. the number of the preceding and following points to be used in smoothing the current point $X(t_n), Y(t_n)$, use the spinboxes on the right of the dialog window.
- If the *'Subtract from Function'* checkbox is checked, the post-filtered values will be subtracted from the pre-filtered ones. Therefore, this option is useful when estimating an observable's noise level (it will however work for slowly-varying processes).
- If the *'Subtract Linear Trend'* checkbox is checked, the program will evaluate the observable's linear trend (by using the linear regression analysis) and then 'subtract' this trend from the original curve.

10.3 'Raw Data Graph' Window

10.3.1 Displaying a Single Observable Function or Macro

When the *'Function Parameters'* dialog window is no longer required, press ***OK***.

A window with the desired *diagram* (also referred to as *plot*) will appear (see the example plot with three carrier phase curves, Figure 10-16):

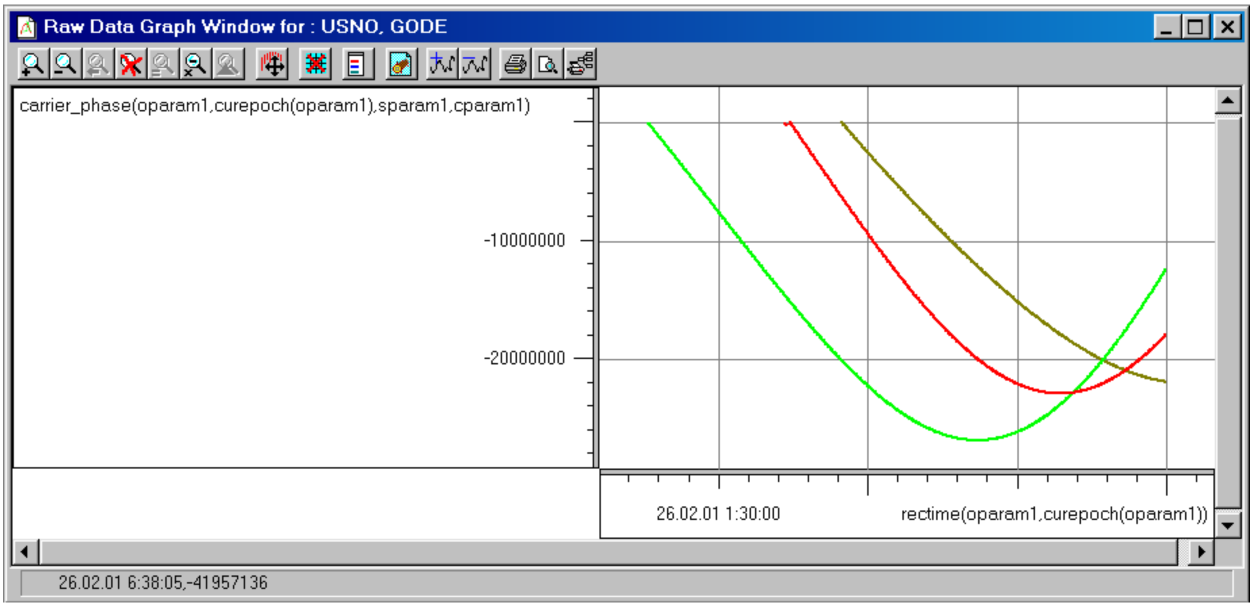


Figure 10-6

Right-clicking on a (carrier phase) curve in the plot area will invoke a pull-down menu with the options *'Delete'*, *'Edit function…'*, *'Edit parameters…'*, *'Curve info…'*, *'To Buffer'* and *'Split from here…'*

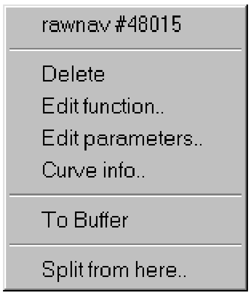


Figure 10-7

The *'Delete'* option is used to remove the entire plot (i.e. all the curves belonging to this plot) from the plot area.

The *'Edit function…'* option is used to activate the *Function Editor*. With this editor the given plot (for the selected observable or macro type) can be replaced with a new plot (for some other observable or macro).

The *'Edit parameters…'* option is used to open the *Function Parameters* window so that the user can update the arguments for the entire plot if necessary.

The *'Curve info…'* option is used to obtain some basic statistical information on each of the curves belonging to the given plot (curve type, number of points, mean FX and FY values, standard deviations of FX and FY values , 99% confidence intervals with respect to the mean FX and FY values).

Note that the *'Curve info…'* dialog window can be invoked for a plot even if this plot is unchecked in the *'Legend'* window. To open the dialog window, right-click on the desired plot (whether or not it is checked) in the 'Legend' window.

The *'To Buffer'* option is a 'bridge' between *Raw Data Graph* and *Epoch View.* This option allows the user to select a specific time interval while viewing a plot in *Raw Data Graph*, save this time interval to the buffer and automatically retrieve it back (through "*From Buffer*") after changing from *Raw Data Graph* to *Epoch View.*

To select a desired time interval when in the plot area of *Raw Data Graph*, the user will move the cursor as close as possible to the left-hand boundary of the interval, press the left-mouse-button and then move the cursor towards the right-hand boundary while holding down the left mouse button. (The user will see a dotted-line rectangular appear in the plot area while dragging the cursor to the right. The vertical sides of the rectangle will specify the start and end times of the interval.)

Once the user has changed from *Raw Data Graph* to *Epoch View,* right-click in an empty area of *Epoch View* 's left-hand panel and select "*From Buffer*" from the pop-up menu. In the right-hand panel, the user will then see raw data corresponding to the specified interval of interest.

The *'Split from here…'* option allows the user to divide the selected occupation into two parts. The split boundary will depend on the cursor position relative to the time axis at command execution. After this command is executed, the corresponding raw data session will have two splits instead of the original occupation. The splits will be named "*<original occupation name>(Head)"* and "*<original occupation name>(Tail)"*, where the string *<original occupation name>* stands for the name of the original occupation.

10.3.2 Displaying Multiple Observable Functions or Macros

In the previous section, consideration was given to the simplest case: a single observable function (specifically, "*carrier_phase*") was called producing a set of homogenous curves in the plot area. *'Homogenous'* means that all of these curves are of the same 'nature' (carrier phases in our example) sharing the same X,Y-axes. In this section, a general scenario will be considered where <u>different</u> observables and/or macros are displayed in the same *Raw Data Graph* window.
Assume it is necessary to display a number of different observables available for two arbitrarily chosen occupations in the same window (in our example below, it will be the occupations GODE and USNO):

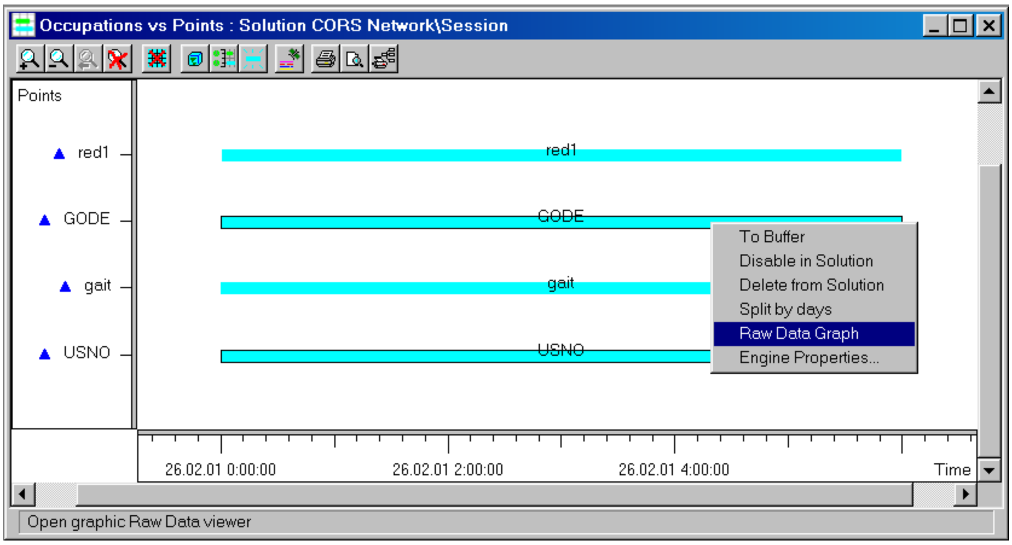


Figure 10-8

First, check these occupations in the *Raw Data Sessions* panel. Second, right-click on the session name and select the ‘Occupation view’ from the pop-up menu. Third, select the two desired occupations in the occupation view with the mouse and the ‘Shift’ key. Fourth, right-click on either of the selected occupations and select the ‘Raw Data Graph’ option from the drop-down menu.

Assume that the user begins by drawing a single difference carrier phase plot for the occupation "USNO". It can be easily achieved by using one of the pre-defined macros (*CarrierPhaseDiff1*). Having selected the *'rectime'* function for the X-axis and necessary arguments for the *CarrierPhaseDiff1* macro (the occupation name, a pair of satellites, and a channel slot), a plot similar to that shown in Figure 10-9 will be achieved:

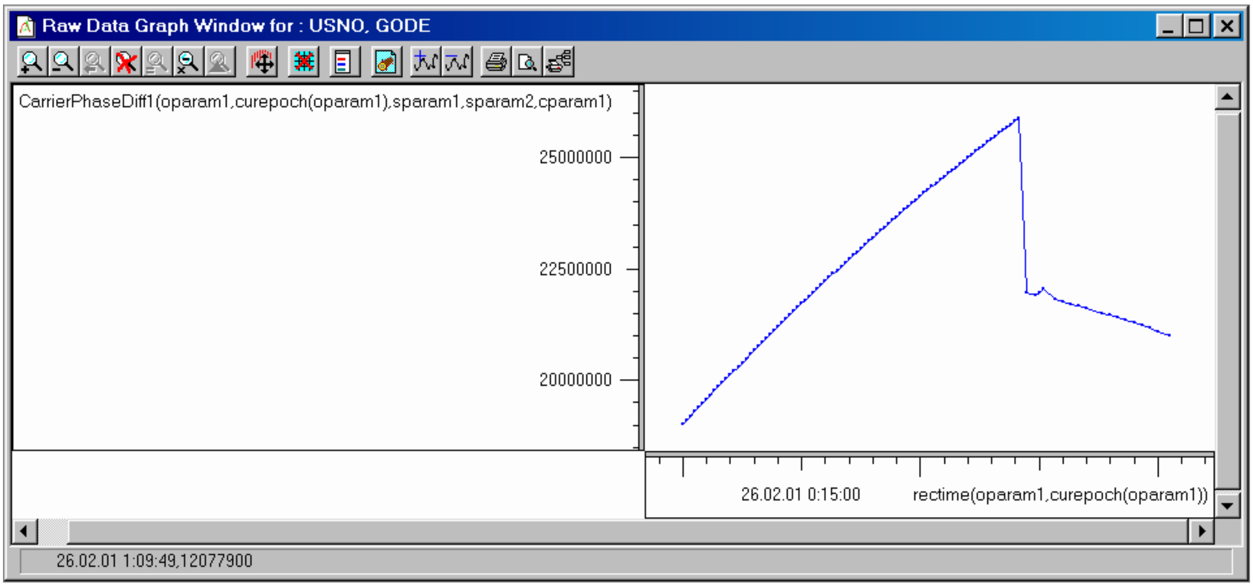


Figure 10-9

At this point, it is possible to:

- remove this *CarrierPhaseDiff1* plot from the plot area altogether
- edit this plot
- change zoom levels
- drag the plot
- show/hide the grid lines
- replace the current function with a new one
- add another function, or
- retain the curve as it is.

There are two means for handling plots in ***Raw Data Graph***:

#1: By using the context menu (to invoke this pop-up menu, the user will right-click in an empty part of the plot area)

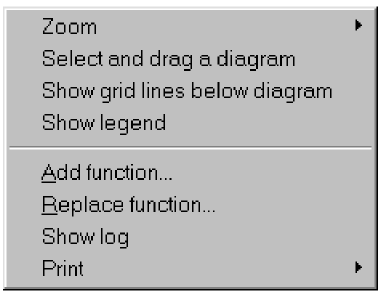


Figure 10-10

#2: By using the *Raw Data Graph* window's toolbar.

To specify necessary zoom levels, the user will expand the zoom node and select the required option from the daughter menu as shown below

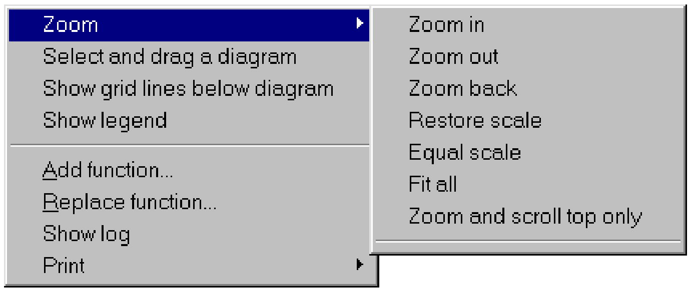


Figure 10-11

The following table shows the correspondence between the context menu's options and their toolbar equivalents.

Table 3

Menu option	***Toolbar button***
Zoom in	
Zoom out	
Zoom back	
Restore scale	
Equal scale	
Fit all	
Zoom and scroll top only	
Select and drag a diagram	
Show grid lines below diagram	
Show legend	
Show log	
Add function…	
Replace function…	
Print	
Print preview	
Print setup	

In order to add more graphical data to the plot shown in Figure 10-9:

Click on the button in the *Raw Data Graph* window's toolbar to activate the *Function Editor*.

After the *Function Editor* is opened, select the carrier phase *('carrier_phase')* for the Y-axis and *'curepoch'* for the X-axis. To fully define FY-expression, it is necessary to choose an occupation (this time "GODE"), a satellite and a channel.

Then repeat the add procedure but select the pseudo range (*'pseudo_range'*) for the Y-axis and *'curepoch'* for the X-axis.

The *Raw Data Graph* window will be shown as follows:

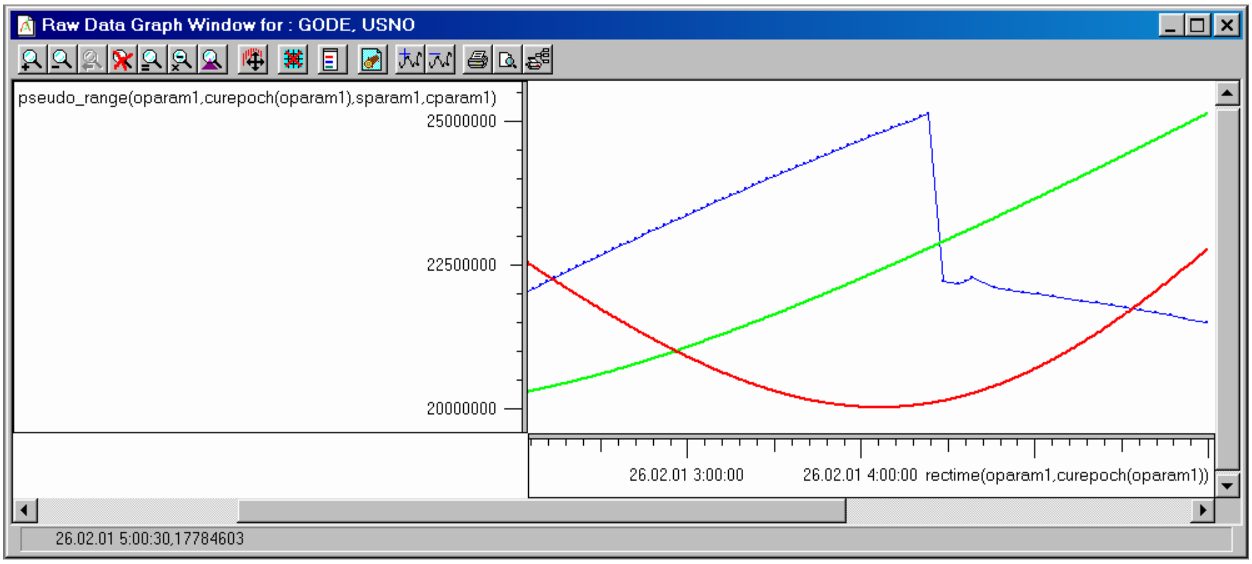


Figure 10-12

Although there are three curves displayed in the plot area in this example, the axes will comply only with the pseudo range plot (the red curve). What will the user do to make the axes match some other plot (or curve) drawn in the plot area?

Note that the X,Y-axes will always match the plot that is shown first in the *Legend* tree. Therefore if the axes are required to match a specific curve, this curve must be topmost in the tree. This operation is called "switching between different plots in the *Raw Data Graph* window".

Example. Assume the axes are required to match the undifferenced carrier phase plot (the light green curve in Figure 10-12). Take the following steps:

1) Press the button  on the toolbar. A *'Legend'* pull-down window will appear (see Figure 10-13):

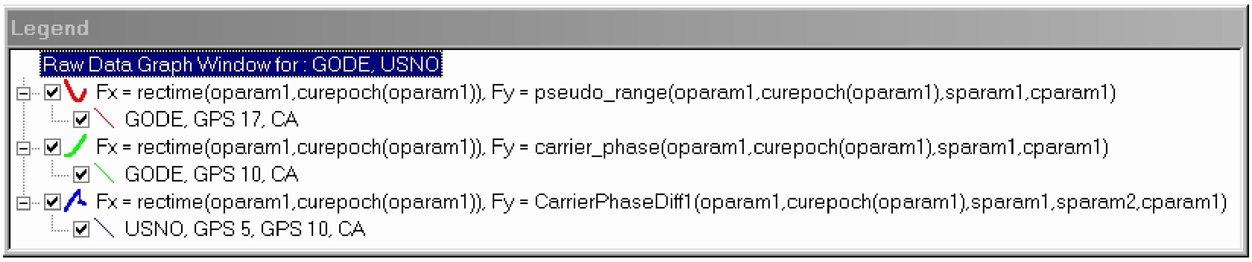


Figure 10-13

2) In the *Legend* window, right-click on the plot required to become topmost (recall that it is the green curve in this example). A small pop-up menu will appear (see Figure 10-14):

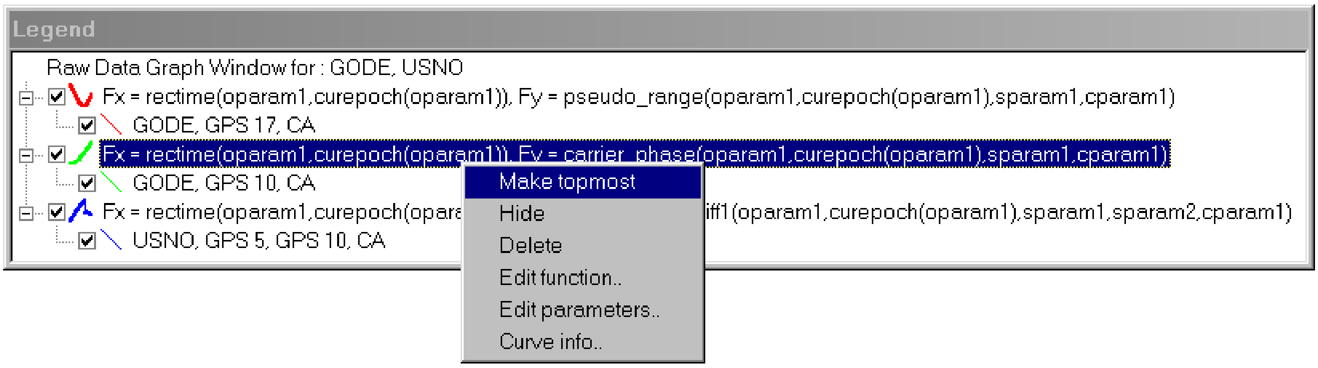


Figure 10-14

3) Select the *'Make topmost'* option to obtain the axes to match the desired plot. The selected plot will become topmost in the 'Legend' tree (Figure 10-15):

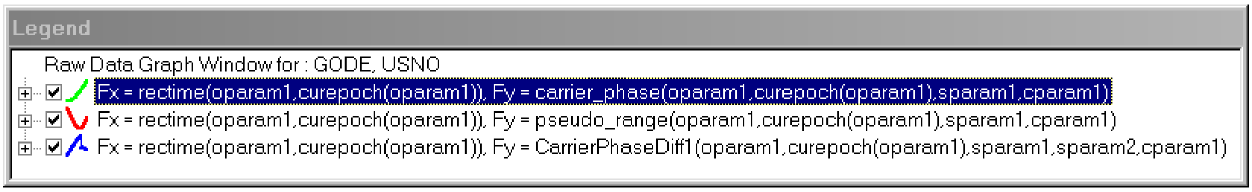


Figure 10-15

Figure 10-16 shows how the axes have changed after *"switching from the red curve to the green one"*.

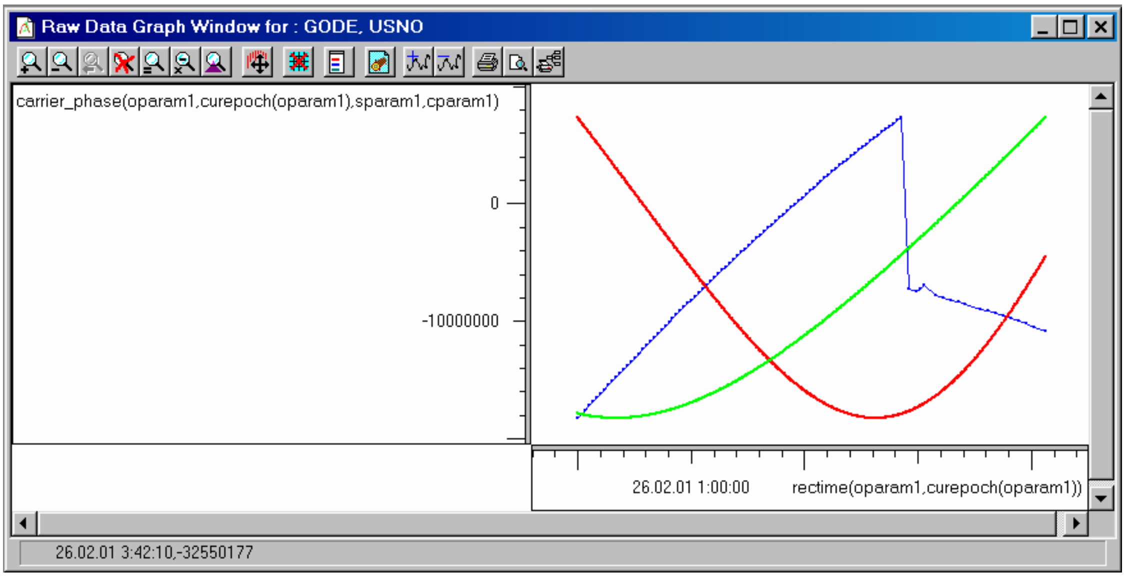


Figure 10-16

10.3.3 List of 'Observable Functions'

Returning to the list of the *'observable functions'* available in ***Raw Data Graph***. These observable functions can take the following 'data types':

- *Occupation,*
- *Epoch number* (as applied to the specified occupation(s)),
- *Satellite,*

- *Channe,l*
- *Coordinate system.*

Although a predefined observable function may have only *one* argument of each type *at a time*, the user is allowed to select the desired "occupation", "satellite" or "channel" from the following numerated argument quadruplets:

- *occupation1, occupation2, occupation3, occupation4*
- *satellite1, satellite2, satellite3, satellite4*
- *channel1, channel2, channel3, channel4*

This mechanism allows the construction of complex functions and macros (taking, say, a dozen arguments) from relatively simple 'elementary' observable functions. This mechanism was designed for broadly used observable combinations such as double and triple difference carrier phases, etc.

alt_dt(occupation, epochnum) - Designates 'local clock versus alternative navigation system clock offset'. In most cases, GPS&GLONASS receivers only provide the clock offset between the *local receiver time* and the so-called *reference time scale* (GPS being the default reference clock). Therefore, the alt_dt function shows the offset between the local receiver time and the other (non-reference) time scale. Note that the current version of *Raw Data Graph* will properly perform this function only if *alt_dt* estimates are present in the file(s) imported into the project. Otherwise a *'Function is undefined'* warning is reported.

carrier_phase(occupation, epochnum, satellite, channel) - Undifferenced carrier phase observables.

channel(occupation,epochnum,satellite) - Receiver channel (C/A, L1P, L2P).

curepoch(occupation) - This function plays a very important part in ***Raw Data Graph*** (see above). It allows the user to avoid entering time arguments explicitly, which would be very tedious in many cases. This function, when called up, will return the actual number for the corresponding epoch.

dllsn(occupation, epochnum, satellite, channel) - Describes the channel *signal to noise* ratios relating to the delay lock loops. Note that a conditional measurement scale is used here, not dB*Hz's (this function will return values varying between 1 and 8 inclusive).

Note. If the raw data measurements are taken from a JPS file (not a Rinex observation file), the user can select to view the *signal to noise* ratios in dB*Hz's. It can be achieved by adding[18] the line *"EnergyPotential=1*" to the section *[JPS Filter]* in the file *Pinnacle.ini*[19]*,* e.g.:

```
[JPS Filter]
HeaderJPSInIniFile=1
……………………
EnergyPotential=1
…………………..
```

[18]) This change must be made *before* running Pinnacle of course.

[19]) Recall that this file resides in the Windows directory.

doppler(occupation, epochnum, satellite, channel) - This function describes the so-called 'full doppler' (or 'carrier phase time derivative'). It is measured in Hz.

elevation(occupation, epochnum, satellite) - Satellite elevation angle at the specified epoch (in degrees).

epochs(occupation) - This functions will return the number of epochs within the given occupation.

fstepoch(occupation) - This is a special-purpose function returning the very first epoch of the given occupation. Mainly used when building dedicated macros.

glonasssats(occupation, epochnum) - This function will return the total number of GLONASS satellites available in epoch *'epochnum'* of the specified occupation.

gpsssats(occupation, epochnum) - This function will return the total number of GPS satellites available in epoch 'epochnum' of the specified occupation.

hassat(occupation, epochnum, satellite) – This will return unity if the specified satellite is available in epoch *'epochnum'* of the specified occupation. Otherwise, a 'Function is undefined' error is reported.

isglonass(satellite) – This will return unity for GLONASS satellites (otherwise zero).

isgps(satellite) – This will return unity for GPS satellites (otherwise zero).

letter(satellite) - For GLONASS satellites, returns their frequency numbers.

numsats(occupation, epochnum) - Returns the total number of satellites (both GPS and GLONASS) available in epoch *'epochnum'* of the specified occupation.

pdop(occupation, epochnum) – This will return PDOP values.

pllsn(occupation, epochnum, satellite, channel) – This will return the channel S/N ratios as measured by the phase lock loop control.

pseudo_range(occupation, epochnum, satellite, channel) - This function will return pseudo ranges, in meters.

recclockoffs(occupation, epochnum) - This will return receiver clock offsets (in seconds).

rectime(occupation, epochnum) - This is another 'core' function broadly used in *Raw Data Graph* tasks. This function will return for epoch *'epochnum'* its receiver time.

smoothing(occupation, epochnum, satellite, channel) - This will return the 'smoothing correction' (in meters) to the pseudo range measured in epoch *'epochnum'*.

tdot(occupation, epochnum) - This will return the receiver clock offset rate (sec/sec).

x(occupation, epochnum, coordsystem) - This function will return the X-coordinate (in the coordinate system *'coordsystem'*) computed in epoch *'epochnum'.*

xdot(occupation,epochnum) - This function will return the X-component of velocity in epoch *'epochnum'* (in meter/sec).

y(occupation,epochnum,coordsystem) - This function will return the Y-coordinate (in the coordinate system *'coordsystem'*) in epoch *'epochnum'.*

ydot(occupation,epochnum) - This function will return the Y-component of velocity in epoch *'epochnum'* (meter/sec).

z(occupation,epochnum,coordsystem) - This function will return the Z-coordinate (in the coordinate system *'coordsystem')* in epoch *'epochnum'*.

zdot(occupation,epochnum) - This function will return the Z-component of velocity in epoch *'epochnum'* (meter/sec).

10.3.4 List of Predefined Macros

Macro is a named expression built up from observable functions, mathematical functions, arithmetic operators, constants and other macros (note that the recursive use of macros is forbidden). A macro may have up to four arguments for each of the following data types:

- *Occupation* (oparam1, oparam2, oparam3, oparam4)
- *Epoch number* (eparam1, eparam2, eparam3, eparam4)
- *Satellite* (sparam1, sparam2, sparam3, sparam4)
- *Channel* (cparam1, cparam2, cparam3, cparam4)

To open the list of the predefined macros, select *'Macros'* in the *'Function Editor'* dialog window:

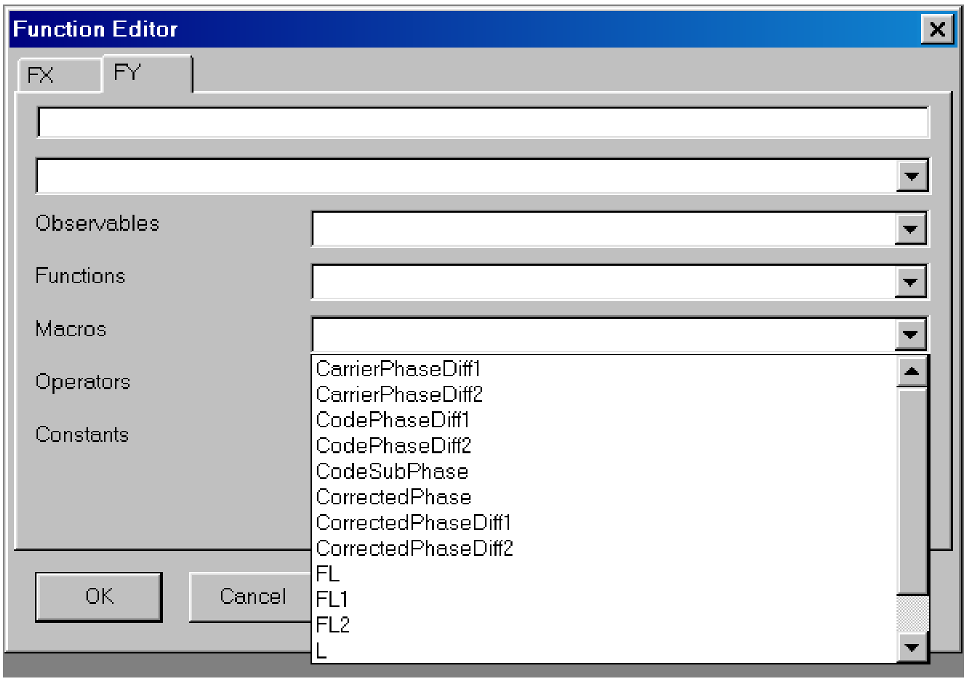


Figure 10-17

For example, select the macro *Double Difference Carrier Phase* from the list. (It is *assumed in this example that a pair of occupations have been checked in the 'Raw Data Sessions' panel of this demo project. Otherwise it will not be possible to select 'oparam1' and 'oparam2' properly.)*

The following pull-down menu will appear:

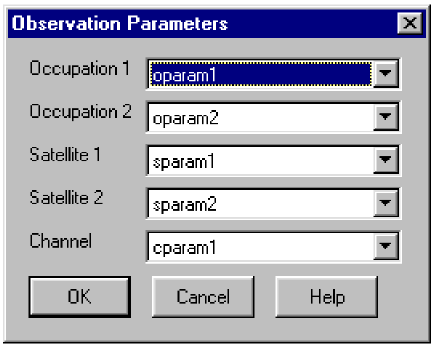


Figure 10-18

Assume the user wants to leave all the five parameters in the *'Observation Parameters'* dialog box as they are. Press 'OK'. This will bring the user back to the *'Function Editor'* dialog window:

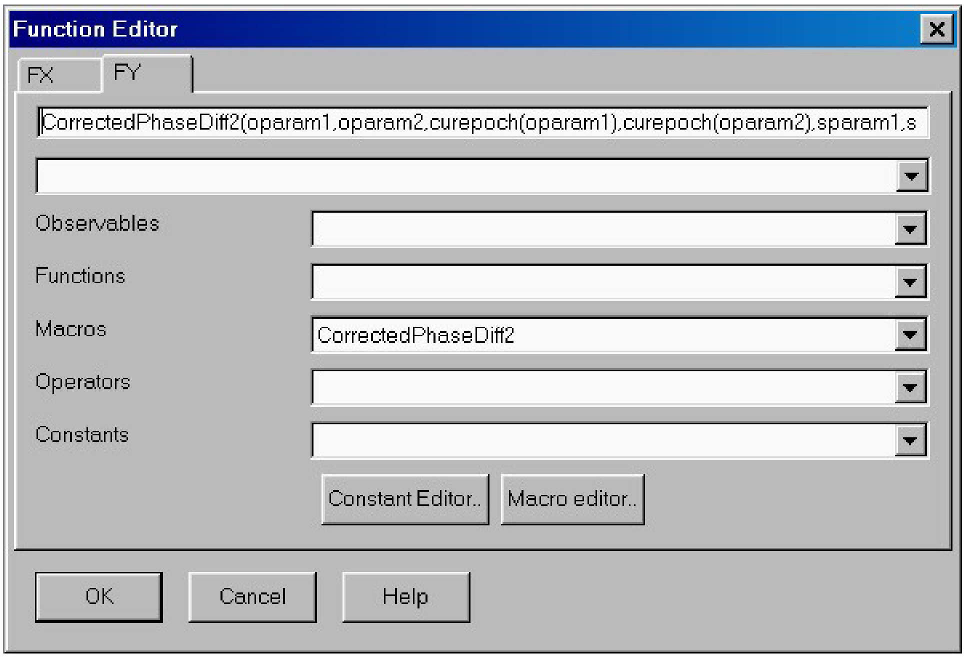


Figure 10-19

In the FX tab, go to the *'Observable'* list box and select the *rectime* function. Press 'OK'. The *'Function Parameters'* dialog window will appear.

The further steps will be as follows:

1) Select the argument "oparam1" from the *'Occupation1'* list box (in this example, "USNO"
2) Select the argument "oparam2" from the *'Occupation2'* list box (in this example, "GODE").
3) Select the argument "sparam1" from the *'Satellite1'* box (in this example, "GPS10").
4) Select the argument "sparam2" from the *'Satellite2'* box (in this example, "GPS30").
5) Finally, select "cparam1" from the channel list box (in this example, "CA").

At this point, the *'Function parameters'* window will look like this:

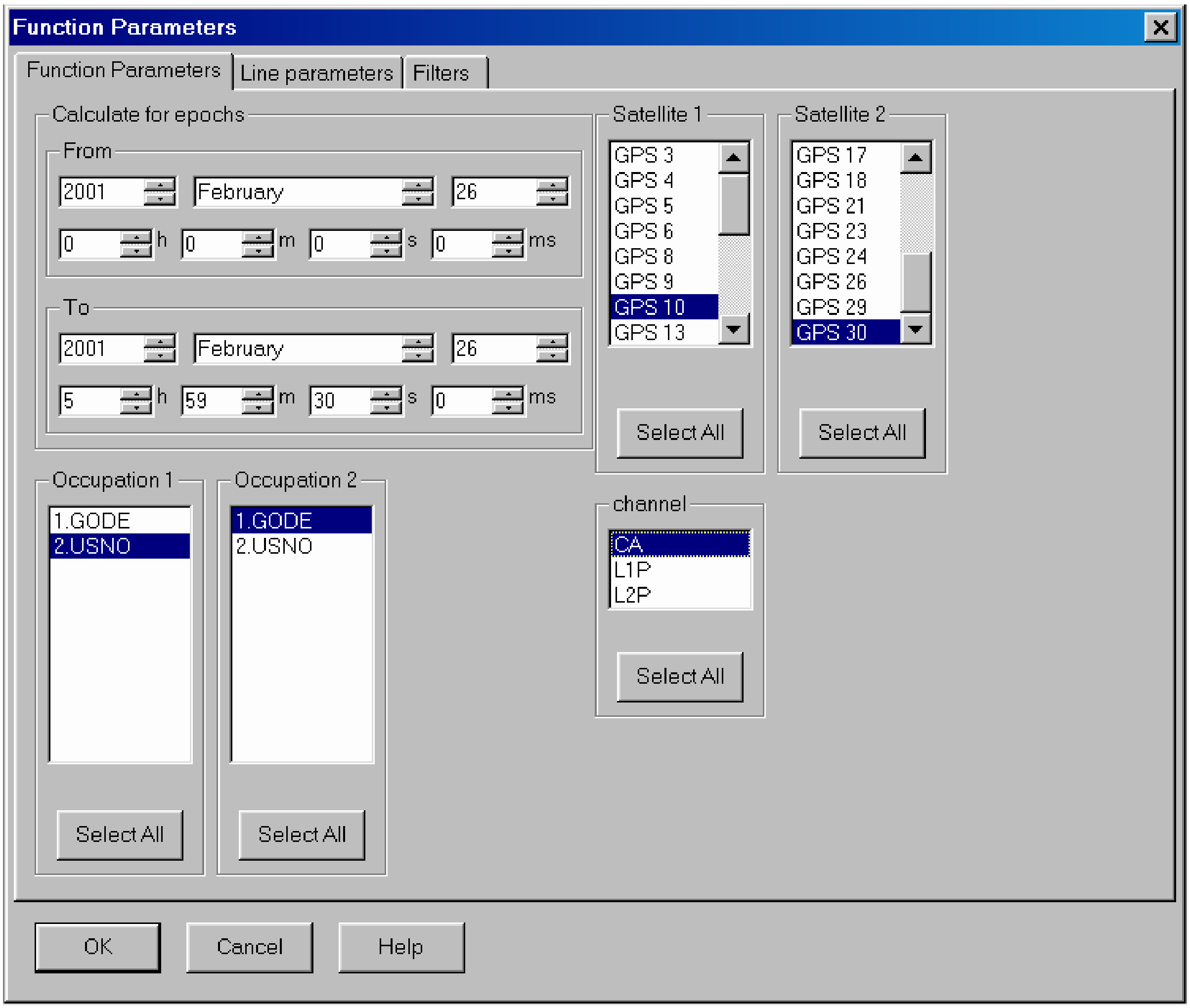


Figure 10-20

Finally, press 'OK' to get *Raw Data Graph* to draw the required DD carrier phase plot:

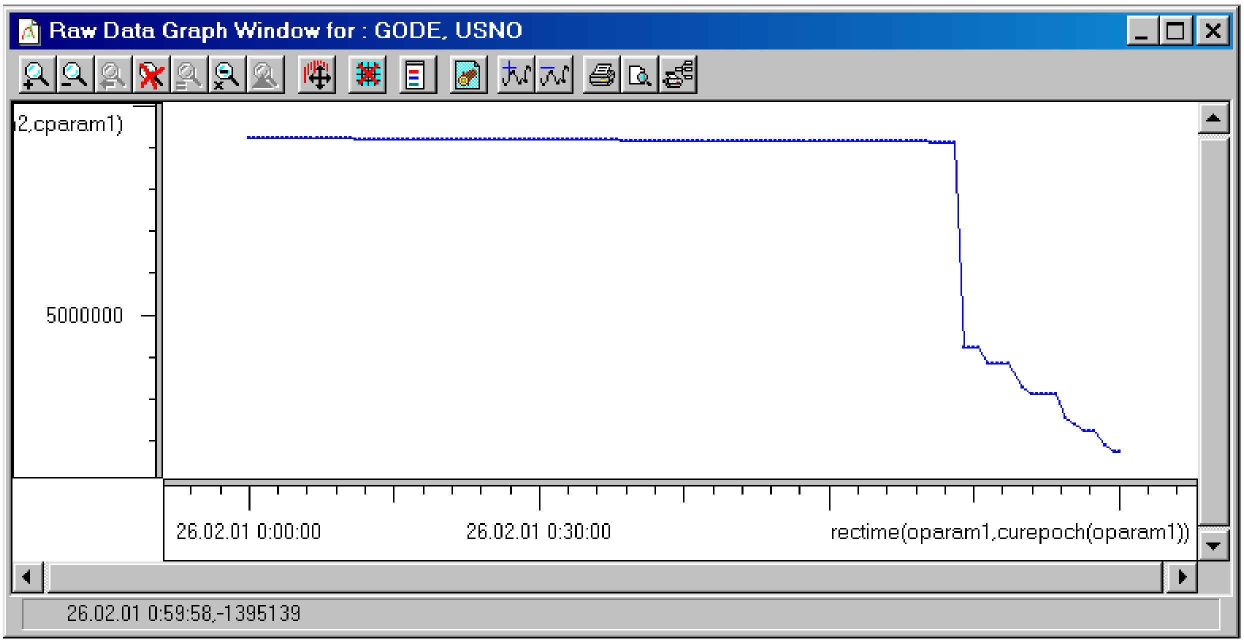


Figure 10-21

So far a pre-defined macro has been used. The following explains how the user can create a macro on his or her own.

To do this, the user must press the *'Macro Editor…'* button in the *'Function Editor'* dialog window.

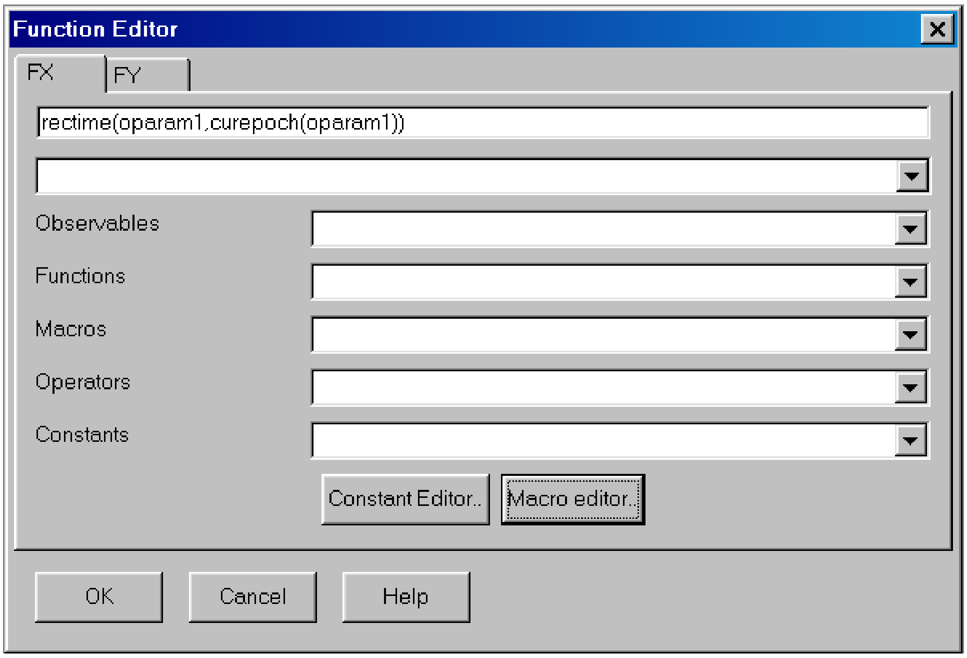


Figure 10-22

A *'Macro Editor'* dialog box will appear.

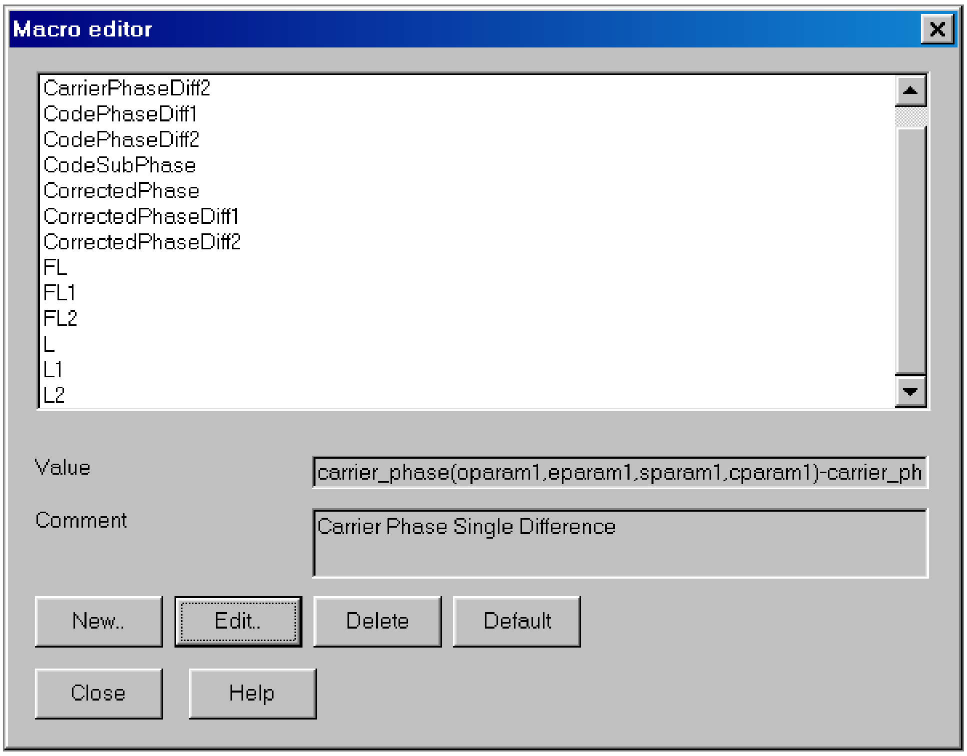


Figure 10-23

Press the *'New'* button if you need to create a new macro, or press the *'Edit…'* button if you want to update an existing macro.

A *'Edit macro'* dialog box will appear as shown in Figure 10-24:

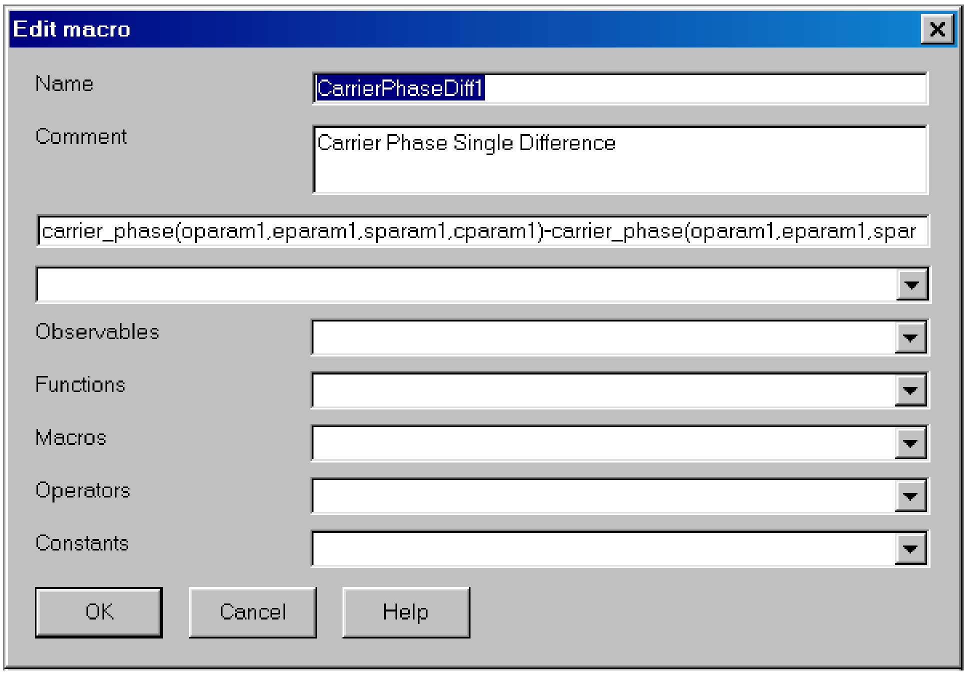


Figure 10-24

Type a new macro or make necessary corrections to an existing one and then press 'OK'. (Make sure that the new macro has a unique name).

To delete a macro, select it and press *'Delete'*.

If the *'Default'* button is pressed, all of the user-defined macros will be **removed** whereas all of the previously deleted 'in-build macros' will be restored to the list.

The list of the predefined macros, which concludes this section, is shown below:

CarrierPhaseDiff1(occupation, epochnum, satellite1, satellite2, channel) returns single difference carrier phases.

CarrierPhaseDiff2(occupation1, occupation2, epochnum1, epochnum2, satellite1, satellite2, channel) returns double difference carrier phase observables.

CodePhaseDiff1(occupation, epochnum, satellite1, satellite2, channel) returns single difference pseudo ranges.

CodePhaseDiff2(occupation1, occupation2, epochnum1, epochnum2, satellite1, satellite2, channel) returns double difference pseudo ranges.

CodeSubPhase(occupation, epochnum, satellite, channel) computes the combination "code phase minus carrier phase".

Note. Please disregard the other predefined macros in this list ("CorrectedPhase", "CorrectedPhaseDiff1", "CorrectedPhaseDiff2", "FL", "FL1", "FL2", "L", "L1", "L2", etc.). These have used merely to debug the program and will not be included in the next release of PINNACLE.

11 References

[1] Pinnacle™ Reference Documentation Suite. Reports. July, 2001
[2] Pinnacle™ Reference Documentation Suite. Event editor. July, 2001

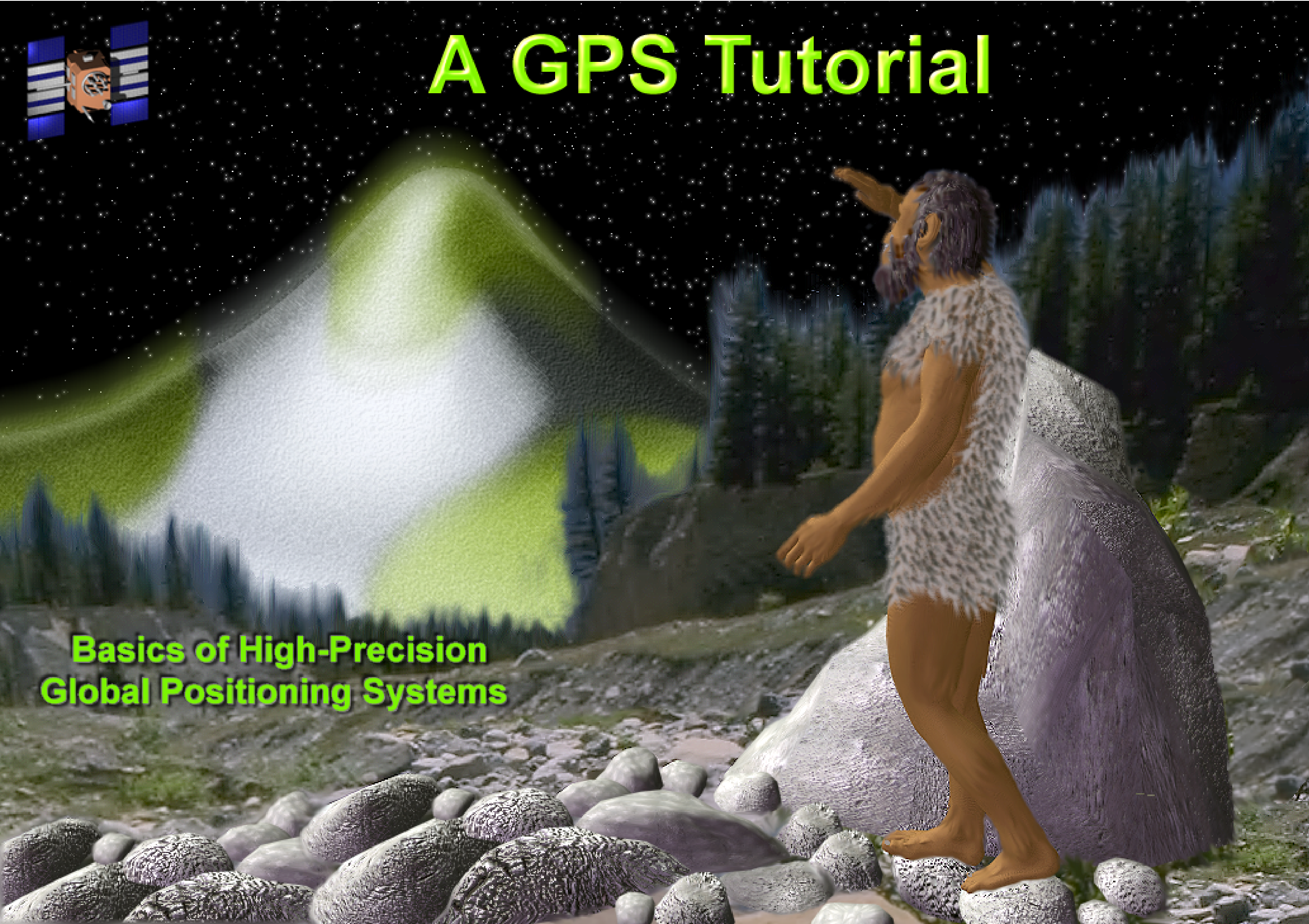

A GPS Tutorial
Basics of High-Precision
Global Positioning Systems

Table of Contents

Chapter 1. From Stones to Satellites

Where am I? How do I get to my destination? These questions are as old as the history of mankind.

The Stone Age

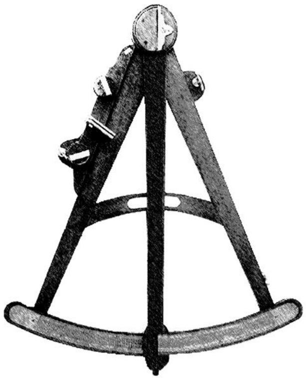
Identifying and remembering objects and landmarks as ***points of reference*** were the techniques that the early man used to find his way through jungles and deserts. Leaving stones, marking trees, referencing mountains were the early navigational aids. Stones, trees and mountains were the early examples of "points of reference", a concept that has evolved through times with the advent of (and the need for) more sophisticated techniques, objects and instruments.

The Star Age

Identifying points of reference was easy on land; but it became a matter of life and survival when man started to explore the oceans, where the only visible objects were the Sun, the Moon and the stars. Naturally, they became the "points of reference" and the era of celestial navigation began.

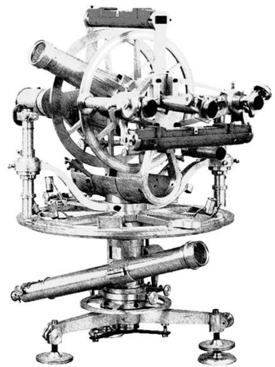
Celestial navigation was the first serious solution to the problem of finding one's position in unknown territories, where the Sun, the Moon and stars were used as points of reference. The relative position of stars and their geometrical arrangement look different from different locations on Earth. Therefore, by observing the configuration of stars one could estimate his position on Earth and the direction that he should take for his destination. The Great Bear and Small Bear constellations are two examples. The geometrical configurations of stars from the observer's point of view were more accurately determined later by measuring the relative angles between them. For better accuracy, special optical instruments were invented to measure the angles of view between stars. These measured angles were then used to determine the position of the observer with the aid of published pre-calculated charts that eased the tedious computation task.

The process of measuring the angles of the stars with optical instruments was time-consuming and inaccurate. It could not be used during the day or on cloudy nights. The measured angles had to be transferred to special charts and after tedious calculations, the derived position was good only to about several miles.



The calculation process was the basic triangulation geometry, where the stars became the known points of reference and the measured angles between them and the navigator would solve for the triangles' components and determine the navigator's position.

The triangulation would have been simpler if distances to the stars could have been measured also. In fact, they could have been used to solve for the triangle's components instead of angles, but such measurements were not possible.



In frustrated moments of trying to determine a position, many navigators must have dreamed, conceivably, of gadgets that would do such a task automatically and more accurately. There were probably people that pictured a device, or even worked on building one, that aligned itself with stars quickly, measured angles to these points of reference and computed its position automatically.

The idea of automatic computation of position through measurement of distances to points of reference became a reality only recently when radio signals were employed and the age of radio navigation began.

The Radio Age

About the middle of this century, scientists discovered a way to measure distances using radio signals. The concept was to measure the time it took for special radio signals to travel from a transmitting station to a special device designed to receive them. Multiplying the signal travel time by the speed of the signal gives the distance between the transmitter and the receiver. The speed of radio signals is the same as the speed of light — about 300,000,000 meters per second (about 186,500 miles per second). Accurate measurement of signal travel time is important since one microsecond (one millionth of a second) of error in measuring the travel time is equal to 300 meters of error in distance. For precision positioning, therefore, the receiving radio should be able to measure the travel time much better than one millionth of a second, perhaps to one billionth of a second (one nano-second).

How could such a radio signal transmitter-receiver system be used to determine a person's location?

Assume that a transmitting tower is installed at a known point, A, on the earth and we have a special radio that can receive signals from transmitter A and measure the distance to the transmitter. The exact location of point A is programmed in our special radio receiver. We are in some unknown location. We turn on the receiver and measure our distance to the transmitter as 12,325 meters. This does not tell us where we are, but it narrows our position to a point on a circle with the radius of 12,325 meters around the transmitter, as shown in the Figure 1.

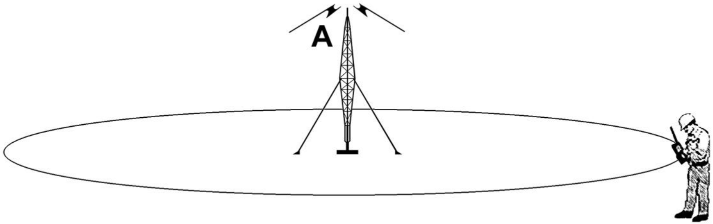


Figure 1

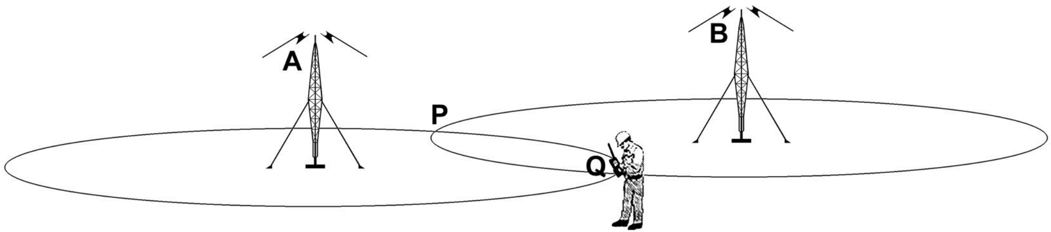


Figure 2

Next, assume that a second transmitter tower is installed at another known point, B, on the earth. The same special receiver measures our distance to transmitter B as 9,792 meters. This tells us that we are somewhere on a circle with the radius of 9,792 around the transmitter B. Now we have two pieces of information: our distance to point A is 12,325 meters and our distance to point B is 9,792 meters. So we are on circle A and circle B at the same time. We must be at the intersection of the two circles, one of the two points P or Q shown in Figure 2.

Measuring our distance to a third transmitter C would identify exactly where we are. Now you can imagine how the system works: we turn on our special radio receiver; it quickly measures the distances to transmitters A, B, and C and will compute our location. Remember that the exact location of transmitters A, B, and C were previously programmed in our special radio receiver. Transmitters A, B, and C together are called a transmitter "chain". A chain may have four or more transmitters in order to have better coverage. The range of a radio transmitter is about 500 kilometers.

Navigational systems that use such radio signals to measure distances to several transmitting towers located at known points are called radio navigation systems.

The LORAN Age

LORAN (LOng RAnge Navigation) is one such radio navigation system that became operational around 1950. Each LORAN chain consists of at least four transmitters and typically covers areas of about 500 miles. To provide LORAN coverage for larger areas, several LORAN chains are used. For example, two LORAN chains cover the West Coast of the United States.

Each LORAN transmitter chain broadcasts radio signals on its own designated frequency. A LORAN receiver tunes in to the radio signals of the transmitters of the chain, measures distances to them automatically, and computes the position of the receiver. A LORAN receiver has the exact locations of all LORAN transmitter chains in its database. In a journey, one may pass through several LORAN chains. So, the navigator needs to know and tune in to the frequency of each LORAN chain he is passing through; in the same manner that one needs to change the frequency of an FM radio when leaving the coverage area of one FM station and entering into a coverage area of another.

The entire operational LORAN chains worldwide cover only a small portion of the earth. They are operated by local governments and are generally situated near coastal areas that have high traffic volume.

Although LORAN was a major breakthrough for navigation, it has the following shortcomings:

- LORAN coverage is limited to about 5% of the surface of the earth where the chains are established. It is not a global system.
- LORAN transmitters send out signals along the surface of the earth and can therefore provide only two-dimensional position information (latitude and longitude). It cannot provide information about height and, for example, cannot be used in aviation to provide altitude.

In general, the accuracy of LORAN is good to only 250 meters.

The Satellite Age

To overcome these limitations, satellite-based radio navigation systems were conceived in which improved radio transmitters were put aboard satellites orbiting the earth at high altitudes to give wider coverage. This is similar to the concept of a local TV station versus satellite TV. You can receive your land-based local TV station only in your city and within a distance of no more than 100 miles, while a satellite TV transmitter can cover an area as wide as the US (about 3000 miles). Signals from navigation satellites can cover large areas of the earth, and several satellites can cover the whole planet.

The theory behind the operation of the satellite navigation systems is similar to that of the land-based systems. In land-based navigation systems, the transmitting towers are the reference points located on the earth and the distance to them is measured by the receivers to compute the two-dimensional position

(Latitude and Longitude or X and Y) by finding the intersection of several circles. In satellite-based systems, the satellites act as the reference points and the distance to them is measured to determine the three-dimensional position (Latitude, Longitude, and Altitude or X, Y, and Z) by finding the intersection of several spheres.

In land-based systems, the location of the transmitting towers are fixed, accurately known, and stored in the data base of the receivers. In satellite-based systems, the locations of the satellites are not fixed. They orbit the earth at high speeds. However, satellites have a mechanism of giving information about their location at any instant in time. The accuracy of the calculated location of the satellites, at the time at which distances to them are measured, affects the accuracy of calculated position of the receiver. In other words, the accuracy in computing our position depends on the accuracy in computing the location of our reference points.

In a positioning satellite system, satellite locations and their orbits are continuously monitored from several observation centers around the world by the organization responsible for keeping the orbit of the satellite within acceptable boundaries. This organization also predicts the orbit of the satellite for the next 24 hours based on the actual orbit information received by the observation posts for the previous 24 hours (similar to weather predictions). The predicted orbit information for the next 24 hours is relayed to each satellite by the control organization, so that it can be sent to receivers. Satellites broadcast their orbit information as part of their radio signal structure.

With satellite systems, we are once again "looking" up to the sky. This time, however, we are "looking" at man-made objects instead of stars. And unlike celestial navigation utilizing stars, man has now devised a scheme (using radio signals and receivers) to measure distances to reference points.

One of the first satellite navigation systems was Transit. The experience gained from Transit and several other experimental systems led to the development of the current Global Positioning System (***GPS***) by the United States of America and GLObal Navigation Satellite Systems (***GLONASS***) by the Russian Federation. GPS and GLONASS are very similar, as we will discuss in the rest of this book.

Summary

In this chapter, we learned:

- *Stones, trees, and mountains were the early examples of "points of reference".*
- *Celestial navigation was the first serious solution to the problem of finding one's position in unknown territories, where the Sun, the Moon and stars were used as points of reference.*
- *Automatic computation of position, through measurement of distances to points of reference, became a reality only recently, when radio signals were employed and the age of radio navigation began.*
- *LORAN coverage is limited to about 5% of the surface of the earth where the chains are established. It is not a global system.*
- *Signals from navigation satellites can cover large areas of the earth, and several satellites can cover the whole planet.*

Chapter 2. Navigation Satellites

In the previous chapter we discussed that if our distances to several satellites of known locations could be measured, then we can compute our position. We have put forward three major prerequisites:

1. Satellites — We need satellites as our points of reference to which we can measure our distances. At any given time, we also need to know the exact location of each satellite.

   A satellite by itself is nothing more than a vehicle. You may call it a space vehicle. The function of each satellite depends on what equipment it carries. If the equipment on board is something like a TV station, then it becomes a TV satellite. If the equipment on board is weather observation equipment, then it becomes a weather satellite whose function is to prepare large-scale images of clouds, storms, hurricanes, etc. Obviously, we need special satellites for our purpose.

2. Coordinate System — How do we express the location of each satellite and how do we express our position? As we recall from algebra, We can express them with sets of numbers related to some coordinate system. We need to define the coordinate system such that they are recognizable by everyone. Thus, we need a universal coordinate system.

3. Distance Measurement — What type of electronic signals must the satellites emit to enable us measure our distances? How do we measure these distances? How accurately can we measure these distances?

And how do these measurement errors relate to the accuracy of our calculated position? We will attempt to answer these questions in the remainder of this chapter.

Measuring Distances to Satellites

Time Is Distance

Have you noticed that during a thunderstorm, you hear the sound sometime after you see the light? The reason is that sound waves travel much slower than light waves. We can estimate our distance to the storm by measuring the delay between the time that we see the thunder and the time that we hear it. Multiplying this time delay by the speed of sound gives us our distance to the storm (assuming that the light reaches us almost instantaneously compared to sound). Sound travels about 344 meters (1,130 feet) per second in air. So if it takes 2 seconds between the time that we see the lightning and the time that we hear it, our distance to the storm is 2 x 344 = 688 meters. We are calculating the distance to an object by measuring the time that it takes for its signal to reach us.

In the above example, the time that we see the lightning is the time that the sound waves are generated in the storm. Then we start to measure the delay until the time that we hear the sound. In this example, the light is our start signal. What about the cases for which we don't have a start signal? Consider the next example.

Codes and Patterns

Assume that your friend at the end of a large field repeatedly shouts numbers from 1 to 10 at the rate of one count per second (10 seconds for a full cycle of 1 to 10 count). And assume that you are doing the exact same thing, synchronized with him, at the other end of the field. Synchronization between you and him could have been achieved by both starting at an exact second and observing your watches to count 1 number per second. We assume that you both have very accurate watches. Because of the sound travel time, you will hear the number patterns of your friend with a delay relative to your patterns. If you hear your friend's count with a delay of one count relative to yours then your friend must be 344 meters away from you (1 sec x 344 meters/sec = 344 m). This is because the counts are one second apart.

Now assume that you and your friend count twice as fast, two counts in one second. Then at the same distance between you and your friend you will hear a two-count delay. This is because now each count takes 0.5 seconds and each count delay measures 172 meters. If you could count 100 times faster then each count would take 0.01 seconds and each count delay between you and your friend would measure the distance of 3.44 meter. Counting faster is like having a ruler with finer graduation. Of course in real world, you need appropriate devices and instruments to generate and receive very fast counts.

Next assume that you and your friend are far apart and counting very fast, say each count in 0.01 second (each delay count is 3.44 meters), and, as before, both are repeatedly counting from 1 to 10. Assume when you say 7 you hear your friend's voice say 5. You hear a delay count of 2 but you know your distance is more than 6.88 meters. This is because the delay is not just only 2 counts, but rather 2 counts plus some multiples of 10 counts (i.e. some multiples of the pattern cycle). This is as if your measuring tape is not long enough and there are some multiples of the full length of measuring tape plus some fraction. We refer to this unknown number of full pattern delays as ***unknown integer***. If you and your friend were to count repeatedly from 1 to 1000 (instead of 1 to 10) then you could hear 212 count delays between the numbers that you hear and your numbers, which would produce the distance of 212 count delays x 3.44 meters = 729.28 meters. This is 21 full cycles of the 1-to-10 pattern, plus 2 counts. The number of full cycles, 21, that we were not able to observe with our short pattern is our unknown integer.

What we demonstrated above are the concepts of *pattern granularity* (fineness of tape marks) and *pattern length* (tape length).

The concept of measuring distances to satellites is much like what we discussed above, but satellites transmit electronic patterns rather than voice counts. Likewise, our receiver generates similar electronic patterns for comparison with the received patterns from satellites in order to measure the distances to them.

Satellites generate two types of patterns: One has a granularity of about 1-millimeter and a length of about 20 centimeters. The other has a granularity of about 1 meter and effectively an unlimited length. In satellite terminology, the first pattern is called ***"carrier"*** and the second is called ***"code"***. The distance measured by carrier is called ***"carrier phase"*** and the distance measured by code is called ***"code phase"***. Because code pattern is long, the code phase measurements are complete and do not have any unknown integer. We can measure our distance to a satellite as 19,234,763 meters, for example. In contrast, the carrier pattern is short and carrier phase has a large unknown integer. You may think that it is useless to say, for example, that our distance to satellite is 13.2 centimeters plus an unknown number of carrier cycles. The unknown integer is in the order of several tens of millions. You may ask what good will it do to measure the fractional part so accurate when millions of full cycles are missing? We will explain more.

Initial Unknown Integer (Integer Ambiguity)

In the previous counting example with a short pattern, assume that you and your friend are standing next to each other and synchronized together counting fast from 1 to 10. You hear no delay because you are standing next to each other. Then your friend starts to move away. The count delays start to grow from 0 (no delay) to 9. After it reaches 9 it will drop back to 0. This is actually 10 and not zero. You know that this is the case (that the zero count delay actually represents one full cycle count) because you have been following the count delays continuously. You will keep in mind, as your friend moves away, to count the whole number of cycles that are being added to your distance. In this case, there is no unknown integer as long as you keep track of him continuously.

If, instead of starting next to each other, you start at some unknown distance, then you are starting from an unknown integer of cycles. However, if after starting your friend moves away from or towards you, you can account for the number of full cycles that must be added to or subtracted from the ***initial unknown integer***. All the distances that you measure every second contains the same initial unknown integer. This is true as long as you keep track of him continuously. If you don't hear him for some period of time, then you don't know how many full cycles he moved and you will have to start with another unknown number of cycles. The point is that as long as you keep track of him you have only one initial unknown integer.

The concepts of code and carrier are very important. Let us use another analogy for better understanding. You may consider that code phase is like a watch that only has an "hours" hand (call it code watch). At any time you can look at this watch and know the time of the day approximately. You may consider carrier phase like a watch that only has a "seconds" hand (call it carrier watch). You can keep track of the elapsed time with this watch with the accuracy of one second as long as you monitor the watch continuously to keep track of the elapsed full minutes. If you somehow can determine the number of full minutes initially (the initial unknown integer when you started looking at this watch) then you can keep track of time very accurately. If you get distracted and lose track of the number of minutes, then you have a new "initial unknown integer" that you somehow must determine again. With code phase watch, you always get the time of the day instantly but with the accuracy of not better than 10 minutes by estimating the location of the hour hand. The code watch can narrow the estimate of unknown minutes (integers) of the carrier watch to plus or minus few minutes. You see that there is a gap between the seconds hand and the hours hand. We are missing the minutes hand. GPS manufacturers have developed techniques to narrow the gap such that code phase and carrier phase can make unambiguous and accurate distance measurements as fast as possible. We will explain the reason for the gap later.

The good news is that the integer ambiguity of carrier phase can be determined by tracking satellites for some period of time. This is the fundamental concept in precision applications like geodesy.

With carrier phase, tracking the correct number of full cycles that the distance to satellite is changing is very critical. You will miscalculate this number if you miss a cycle or add an extra cycle. In GPS terminology, this is called a ***"cycle slip"***. In our previous example, cycle slips can happen if you don't hear your friend's voice correctly due to noise or other effects, or if he suddenly jumps a very long distance. Cycle slips is like missing the meter marks while you are concentrating on reading the millimeter ticks. It can create large errors. Most GPS systems are able to detect and repair cycle slips.

Note that not all receivers can measure carrier phase. Carrier phases are typically used in high precision receivers.

We can measure the distances to the satellites with the accuracy of 1 meter with code phase and 1 millimeter with carrier phase. This does not mean that we can determine our position with a GPS receiver with the accuracy of one meter or one millimeter. Several sources introduce inaccuracies into the GPS measurement. We will discuss them in the next Chapter.

Summary

In this chapter, we learned:

- *We can calculate the distance to an object by measuring the time that it takes for its signal to reach us.*
- *Satellites generate two types of patterns, carrier and code. Carrier has a granularity of about 1-millimeter and a length of about 20 centimeters. Code has a granularity of about 1 meter and effectively an unlimited length.*
- *The integer ambiguity of carrier phase can be determined by tracking satellites for some period of time.*

Chapter 3. Sources of Inaccuracy: The Problems

In our discussion of measuring distances using patterns of numbers, we assumed that you and your friend started counting numbers simultaneously. If your watch is one second off, this will translate into 344 meters of error in measuring distance, because sound travels 344 meters in one second. With satellites, the electronic signals travel about 300,000,000 meters per second (the speed of light). So the errors in the satellite clock and the receiver clock contribute profoundly to errors in distance measurements.

Satellite Clock

One billionth of a second (one nanosecond) of inaccuracy in a satellite clock results in about 30 centimeters (one foot) of error in measuring the distance to that satellite. For this reason, the satellites are equipped with very accurate (Cesium) atomic clocks. Even these very accurate clocks accumulate an error of 1 billionth of a second every three hours. To resolve the satellite clock drifts, they are continuously monitored by ground stations and compared with the master control clock systems that are combinations of more than 10 very accurate atomic clocks. The errors and drifts of the satellites' clock are calculated and included in the messages that are transmitted by the satellites. In computing the distance to the satellites, GPS receivers subtract the satellite clock errors from the reported transmit time to come up with the true signal travel time.

Even with the best efforts of the control centers in monitoring the behavior of each satellite clock, their errors cannot be precisely determined. Any remaining satellite clock errors accumulate typically to about a few nanoseconds, which cause a distance error of about one meter.

Receiver Clock

Similar to satellite clock errors, any error in the receiver clock causes inaccuracy in distance measurements. However, it is not practical to equip receivers with very accurate atomic clocks. Atomic clocks weigh more than 20 kilograms, cost about US$50,000, and require extensive care in temperature control.

Assume that at a given time our receiver clock has an error of one millisecond, causing a distance error of about 300,000 meters. If the distances to all satellites are measured exactly at the same time, then they are all off by the same amount of 300,000 meters. We can, therefore, include the receiver clock error as one of the unknowns that we must solve for. Remember from Chapter 1 that we had three unknowns (X, Y, Z) for the position. Now we have four unknowns: three components of position and the new unknown of receiver clock error. We will need four equations in order to solve for the four unknown. Measuring distances to four satellites can provide us such four necessary equations. Instead of three satellites before, now we need four, but in return we can use inexpensive clocks in our GPS receivers.

Note that the concept of receiver clock being one of the unknowns is valid only if we take measurements to all satellites exactly at the same time. If distances to all satellites are not measured at the same time, then for each measurement we have a different clock.

Making simultaneous measurements to four satellites, we not only compute the three dimensions of our position, but we also find the error in our receiver clock with very good accuracy. A typical clock has a drift of about 1000 nanoseconds every second, but we can now adjust the receiver time to the accuracy of the GPS clock. This will make the inexpensive clock of the receiver as good as an atomic clock. Receivers correct their clock every second and provide a corrected tic signal for outside use for those who need accurate time. If we put a receiver in a precisely known location, then we need to track only one satellite to continuously calculate the receiver clock error and adjust it.

Four is the minimum number of satellites that we need to compute position and time. The more satellites we have the more accurate results we can get. This is discussed later in the GDOP section.

Satellite Orbit Error

As we discussed before, the accuracy of our computed position also depends on how accurately we know the location of the satellites (the points of references). The orbits of satellites are monitored continuously from several monitoring stations around the earth and their predicted orbital information is transmitted to the satellites, which they in turn transmit to the receivers. The history of GPS has shown, thus far, that the accuracy of the orbital prediction is in the order of a few meters. This will create about a few meters of error in computing our position. In the next chapter we shall see how to remove this error.

Atmospheric Errors: Ionosphere and Troposphere

Ionosphere

In computing distances to satellites, we first measure the time it takes for the satellite signal to reach the receiver and then we multiply this by the speed of light. The problem is that the speed of light varies due to atmospheric conditions. The upper layer of the atmosphere, called the ionosphere, contains charged particles that slow down the code and speed up the carrier.

The magnitude of the effect of the ionosphere is much more during the day than during the night. The magnitude also has a cyclical period of 11 years that reaches a maximum and a minimum. For the current cycle, the ionosphere will reach its peak magnitude in 1998 and its minimum in 2004. The cycle will then be repeated. The effects of the ionosphere, if not mitigated, can introduce measurement errors greater than 10 meters.

Some receivers use a mathematical model for the effects of the ionosphere. With the approximate knowledge of the density of the charged particles in the ionosphere (broadcast by satellites), the effect of the ionosphere can be reduced by about 50%. The remaining error is still significant.

The impact of the ionosphere on electronic signals depends on the frequency of the signal. The higher the frequency, the less is the impact. So if we transmit the patterns simultaneously via two different frequencies, the ionosphere may delay the code on one frequency, for example, by 5 meters and on the other frequency, say, by 6 meters. We cannot measure the magnitude of these delays, but we can measure their difference by observing the difference on their arrival time, which in this case translates into 1 meter of effective distance between them. By measuring this difference and using known formula for frequency dependency of the ionosphere delay, ionosphere effect can be removed.

It is exactly for this reason that all GPS satellites transmit information in two frequencies, called ***L1*** and ***L2***. Precision receivers track both signals to remove the effect of the ionosphere. All non-precision receivers track only the L1 signal. This is one of the main distinguishing features between different types of receivers. The L1 receivers are also called single frequency receivers, while the receivers that track L1 and L2 are called dual frequency receivers. Dual frequency receivers practically remove the ionosphere effects.

Since the L2 signal is not entirely available to the general public, sophisticated techniques have been implemented in receivers to extract the code and carrier information, even with the partial availability of the L2 signal. These techniques fully satisfy the requirements of the users for non-military applications, while not compromising the Anti Spoof policy and security objectives of the US Department Of Defense (DOD).

There has been some discussion on allowing a different frequency for civilian applications to separate the DOD and civilian requirements. We believe, however, that the existing system fully satisfies the civilian requirement, particularly since advancements in electronics integration have made the technology affordable for broad civilian applications.

Troposphere

The lower level of the atmosphere, which contains water vapors, is called the troposphere. It has the effect of slowing down both code and carrier. The effects of the troposphere cannot be removed using dual frequency systems. The only way to remove the effects of the troposphere is by measuring its water vapor content, temperature and pressure, and applying a mathematical model that can compute the delay of the troposphere.

Multipath

In measuring the distance to each satellite, we assume that the satellite signal travels directly from the satellite to the antenna of the receiver. But in addition to the direct signal, there are reflected signals, from the ground and the objects near the antenna, that also reach the antenna through indirect paths and interfere with the direct signal. The compound signal creates an uncertainty about the true signal arrival time, much the same way as the echo from nearby mountains may cause uncertainty in the exact time you hear your friend's voice. If the indirect path is considerably longer than the direct path (more than 10 meters) such that the two patterns of signals can be separated, then the multipath effect can be substantially reduced by signal processing techniques.

Receiver Errors

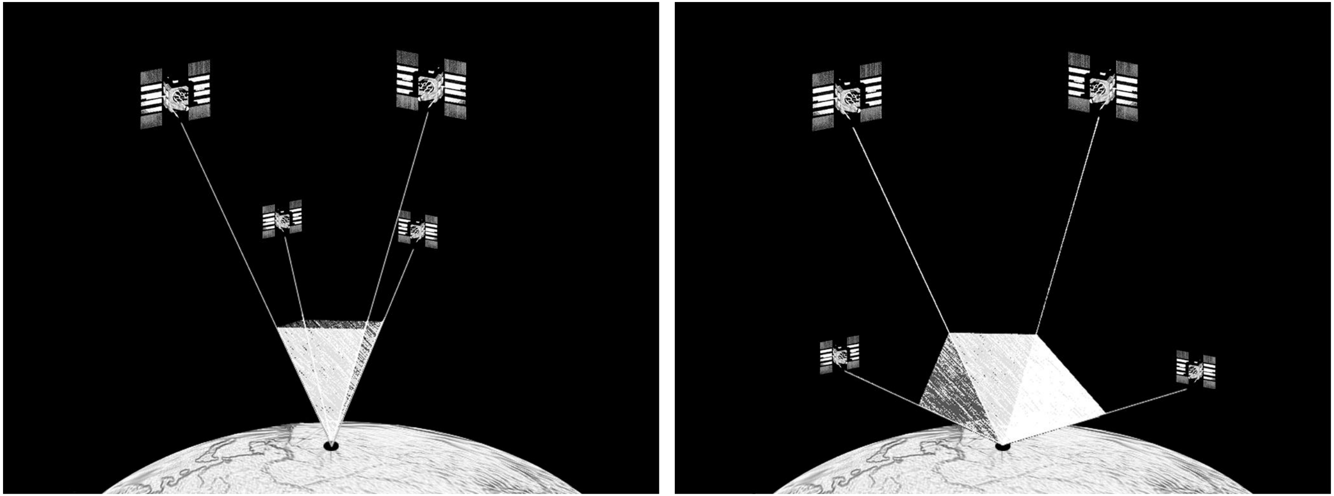
Receivers may introduce some errors by themselves in measuring code or carrier. In high quality receivers, however, these errors are negligible (less than one millimeter) for carrier phase and a few centimeters for code phase.

Geometric Dilution Of Precision (GDOP)

We have been talking about the errors in measuring distances to satellites, which are commonly referred to as ranging or range errors. The question is what is the relationship between the range error and the error in computed position. Or, in other words, how many meters of error are introduced in our computed position as a result of one meter of error in measuring distances to the satellites?

The answer is that it depends on the number and the geometry of the satellites used. If four satellites are clustered near each other, then one meter of error in measuring distance may result in tens or hundreds of meters of error in position. But if many satellites are scattered around the sky, then the position error may be less than 1.5 meters for every meter of error in measuring distances. The effect of the geometry of the satellites on the position error is called Geometric Dilution Of Precision (***GDOP***), which can roughly be interpreted as the ratio of the position error to the range error.

Imagine the tetrahedron that is formed by lines connecting the receiver to each satellite used. The larger the volume of this tetrahedron, the smaller (better) the GDOP. In most cases, the larger the number of satellites the smaller the GDOP.



Selective Availability: The Man-Made Errors

Errors in the satellite clock, the satellite orbit, the ionosphere, the troposphere, the multipath, and the receiver typically amount to less than 10 meters of range error which, under typical GDOPs of about 2, results in a position accuracy of about 20 meters.

The US Department of Defense has determined that providing this level of precision to the general public is against the US national interest. Therefore, DOD has introduced man-made intentional errors to degrade the position accuracy of GPS to about 100 meters. This intentional degradation is called ***Selective Availability (SA)*** and is implemented by tethering the satellite clocks and reporting the orbit of the satellites inaccurately. Military receivers are equipped with special hardware and codes that can mitigate the effect of SA. SA can be turned ON or OFF through ground commands by the GPS system administrators.

Summary

In this chapter, we learned:

- *We can adjust the receiver time to the accuracy of the GPS clock. This will make the inexpensive clock of the receiver as good as an atomic clock.*
- *Four is the minimum number of satellites that we need to compute position and time. (But the more satellites we have the more accurate results we can get.)*
- *Dual frequency receivers practically remove the ionosphere effects.*
- *If the signal indirect path is considerably longer than the direct path, more than 10 meters, then the multipath effect can be substantially reduced by signal processing techniques.*

Chapter 4. Sources of Inaccuracy: The Cures

Neither the accuracy of 100 meters (SA On) nor the accuracy of 20 meters (SA Off) is enough for many civilian applications. Since the inception of GPS, methods have been, and are still being, developed to reduce errors and enhance the accuracy, even with the implementation and presence of SA and partial availability of L2 (AS).

Differential Mode

Assume you have two receivers not too far from each other. The errors due to the satellite clock, the satellite orbit, the ionosphere, the troposphere and SA affect both receivers the same way and with the same magnitude. If we knew the exact location of one receiver, we could use that information to calculate errors in the measurement and then report these errors (or correction values) to the other receiver, so that it could compensate for them. This technique is called Differential mode.

The receiver in the known location is called ***"base receiver"*** and the other receiver with unknown location is called ***"rover receiver".*** The base receiver computes its instantaneous range to each satellite, based on its known position and the instantaneous location of each satellite. Then it compares each calculated value to its measured range for the corresponding satellite. The difference between the two is the range error (or correction value) for the corresponding satellite, which is reported to the rover receiver. The rover receiver subtracts the reported correction values from its measured ranges for all corresponding satellites and computes its own position with much better accuracy.

Due to the motion of the satellites and changes in their clocks, correction values change rapidly with time. Therefore the base receiver must quickly compute the range errors and transmit them to the rover.

Note that the accurate knowledge of the position of the base directly impacts the accuracy of the position computed by the rover. If we enter a position for the base receiver that is off in some direction, then all range errors computed and transmitted by the base receiver will be off in such a way that the computed rover position will be off by the same amount and in the same direction as the base.

The distance between the base and rover receivers is called "baseline". When the baseline is small, i.e. when the receivers are very close to each other, the range errors for the two receivers are nearly identical; therefore, we could use the range errors calculated by the base to correct for the rover position. As the baseline gets longer, the correlation between the range errors becomes weaker. In other words, there will be some residual errors in the computed position of the rover that depend on its proximity to base. As a rule of thumb, you can expect an additional one millimeter of error or uncertainty for every kilometer of baseline when dual frequency receivers are used. This is abbreviated as 1 ppm (one part per million). For single frequency receivers this error increases to 2 ppm.

The differential mode will remove most of all errors except multipath and receiver errors. These errors are local to each receiver and will not be canceled by the differential mode.

The receiver error (or noise) is typically about 10 cm for the code phase and about 1 mm for the carrier phase. In high quality receivers, these errors are even smaller by several times. The multipath error, on the other hand, could be as much as several meters for the code phase and several centimeters for the carrier phase. Therefore, if we somehow deal with the multipath errors, we can obtain millimeter level accuracy with carrier phase and decimeter accuracy with code phase. How to deal with multipath errors is a separate topic that we will cover in Chapter 5; for now let us assume that multipath errors can somehow be mitigated and continue our discussion.

Historically, differential mode with code phase has been called DGPS and with carrier phase called ***Carrier Phase* Differential (CPD)**. Real-time carrier phase differential has been called ***Real-Time Kinematic (RTK)***. In non-real time applications, terms like static or kinematic have been used. Next, we discuss DGPS and RTK. These discussions apply to non-real time applications the same way.

In carrier differential, computations are much more complex because we have to deal with the additional unknowns of initial full cycles. It may take several minutes to determine the full cycle ambiguities. After determining the initial full cycle ambiguities, then each subsequent position computation is instantaneous. As long as a minimum of four (or for reliability five) satellites are tracked, the loss of lock to other satellites will not disturb the continuity of position computation. But as soon as we end up with less than four satellites, then we need to resolve the initial full cycle ambiguities again when we re-lock to satellites, which can take up to several minutes. With code DGPS results are instantaneous, but not as accurate.

DGPS

In DGPS, if range errors are transmitted from the base receiver to the rover receiver in real-time, (i.e. with a radio link) then the system is called real-time DGPS in which accurate results can be obtained in real time. This is desirable for applications in which some actions need to be performed in the field, such as placing markers or moving objects to exact locations. If real time results are not needed (e.g. for making accurate maps), the measurements are time tagged and recorded in the base and rover receivers and later transferred to a computer to calculate the accurate position of the rover the rover at each instant. This is called post-processed DGPS.

DGPS is based on measuring distances to satellites with code phase. Code phase is like a measuring tape that has tic marks and numbers only every meter. The meter-marks and numbers of this measuring tape appear instantly after we lock to satellites, therefor we can measure distances instantly but not accurately.

RTK

RTK is based on measuring distances to the satellites with carrier phase. Another analogy of carrier phase is that it is like a measuring tape that has meter-marks and millimeter-marks. But with this measuring tape the meter-mark numbers do not appear instantly when we lock to satellites. We have to wait for the meter-mark numbers to appear and become clear (like a Polaroid picture) to be able to measure the distances. This is the time that we have to wait to determine the "initial unknown integers". The more we wait the meter-mark numbers become more clear (like a Polaroid picture). When meter-mark numbers become clear they remain clear and we can make instantaneous accurate measurements repeatedly until we lose lock to satellites in which case the meter-marks disappear again. When this happens, we have to wait for them to re-appear after we re-lock to satellites.

You can re-lock to satellites quickly and resolve their integer number immediately if you maintain tracking of at least five satellites.

When satellite interruptions are very brief, receiver may be able to continue based on the integer estimation that it had before.

Estimating the integer numbers incorrectly, or having cycle slips, is like reading the wrong number on the meter-mark. You can imagine examples when you measure something to be 3.874 meter while it actually was 4.874 meter. You read the millimeter-marks very accurately but misread the meter-mark number.

After the receiver resolves the ambiguities correctly, the accuracy of each position computation is between 0.5 to 2 cm horizontal and 1 to 3 cm vertical (depending on antenna multipath rejection capability) plus 1 ppm for double frequency and 2 ppm for single frequency. All RTK accuracy specifications from all manufacturers are within this range. They are all based on the assumption that the integers are estimated correctly.

Resolving the integers correctly is the key in RTK. The big question here is how long it will take to resolve the integers reliably after satellites are locked. If they are resolved incorrectly, it is like reading the meter-number wrong but continue to concentrate on reading the millimeter marks.

How long do I have to wait for the ambiguities to be estimated correctly and with a good assurance?

For short baselines (less than 10 kilometer) the time that you have to wait depends upon:

— The level of assurance (or confidence level) that you require for correct integer estimation.

— The number of satellites.

— Whether you have a single or a dual frequency receiver.

— The strength of the multipath signal (reflection coefficient of ground).

— Multipath mitigation characteristic of the antenna.

The sensitivity of time to resolve the ambiguities to the above factors are described below quantitatively, in order to help you understand the relative importance of each factor:

— Everything else being equal (i.e. for a given set of numbers for all other factors), it may require 10 seconds to resolve ambiguities with 99% confidence but 100 seconds to get to 99.9% confidence.

— Everything else being equal, it may require 1 second to resolve ambiguities with 15 satellites but 100 seconds with 8 satellites. It may take 10 minutes if there are only 6 satellites.

— Everything else being equal, it may require 10 seconds to resolve ambiguities using dual frequency receivers but 2 minutes with single frequency. Having dual frequency for short baselines is like having 50% more satellites. For example if you track dual frequency of 6 satellites, it is like tracking 9 single frequencies in short baselines.

— Everything else being equal, it may require 10 seconds to resolve ambiguities when reflected signal is from a dry ground but 20 seconds when it is reflected from the wet ground. The reflected signal from a wet ground is almost as strong as the direct signal.

— Everything else being equal, it may require 10 seconds to resolve ambiguities with antenna that has good multipath rejection (-35 db down/up ratio) but 200 seconds with a regular antenna (-15 db down/up ratio). Multipath is a main cause of wrong integer estimation.

The number of satellites is the most important factor in resolving ambiguities reliably and quickly. As a rule of thumb, you need at least 8 satellites for short baselines. For short baselines, the role of dual frequency is that it multiplies the number of satellites by 1.5.

For long baselines, you must have at least 8 dual frequency satellites.

With GPS alone only 32% of the time, we have 8 satellites and only 5% of the time 9 satellites and very rarely more than 9.

GPS has 6 or more satellites 96% of the time. So Dual frequency GPS is marginally sufficient for short baseline RTK. This is because 6 dual frequency is equivalent to 9 single frequency for short baselines.

GPS+GLONASS always have 9 or more satellites, 99% of the time more than 10, 96% of the time more than 11 satellites.

Single frequency GPS can rarely work for short baselines RTK and never for long baselines.

Single frequency GPS+GLONASS can always work for short baselines but not for long baselines.

Dual Frequency GPS can always work for short baseline but rarely for long baselines.

Dual frequency GPS+GLONASS is the only RTK system that can always work for short and long baselines.

Adverse Signal Conditions

While, as we discussed above, the number of satellites is key in resolving the ambiguities reliably, there are still other adverse signal conditions like "signal fade-away", "in-band" and "out-of-band interference", and "brownout" that we need to deal with. The receivers used in RTK applications, in particular, need to have higher tracking capabilities and be able to handle these conditions since after any loss of lock we have to wait to resolve the integers again.

In the next chapter, we will describe advancements in GPS technology that improve receiver performance under these conditions, along with the mitigation of multipath errors that we deferred earlier.

Summary

In this chapter, we learned:

- *The accurate knowledge of the base position directly impacts the accuracy of the position computed by the rover.*
- *Differential mode will remove most of all errors except multipath and receiver errors. If multipath errors could be removed, millimeter level accuracy could be obtained with the carrier phase and decimeter level accuracy with the code phase.*
- *DGPS is based on measuring distances to satellites with code phase. We can measure distances instantly but not accurately.*
- *Resolving the integers correctly is the key in RTK. The big question is how long it will take to resolve the integers reliably after satellites are locked.*
- *Dual frequency GPS+GLONASS is the only RTK system that can always work for short and long baselines.*

Chapter 5. Advanced Features

Recent innovations in GPS receiver technology have introduced ways to enhance precision, availability, and reliability in advanced receivers. These innovations address mitigation of multipath errors, receiver (antenna center) stability, and data reliability under adverse signal conditions.

Adverse conditions arise from partial obstructions like canopies and light trees that make satellite signals weak, interference from other communication systems (radio and TV broadcasts, radar, communication satellites, etc.), interference from power lines and transformers, high levels of ionospheric activities that make tracking of L2 signal harder, abrupt motions of the receiver, or momentary signal interruptions like going through a short tunnel that temporarily blocks all satellites. Some of the methods used to deal with these problems are unique to specific receivers, the details of which are beyond the scope of our discussion but may be found in the manufacturers' literature.

Multipath

There are two techniques available to mitigate the effects of multipath: a) Signal processing technique and b) multipath rejection choke rings.

Signal processing technique — In this method, the data is analyzed to separate the direct signal from the indirect signal(s). You can imagine the echo of your voice in a canyon. If the indirect path is substantially longer than the direct path, then you may be able to distinguish the two and concentrate on the direct path. But if the difference is small, the echoed signal may be so close to the direct signal that you cannot separate them. With GPS signals, the signal processing technique is ineffective if the difference between the direct path and the indirect path is less than a few meters. Removing a multipath signal comes at the expense of removing part of the direct signal too, which in turn increases noise. Oftentimes, the more we try to remove the short distance multipath, the more noise we add.

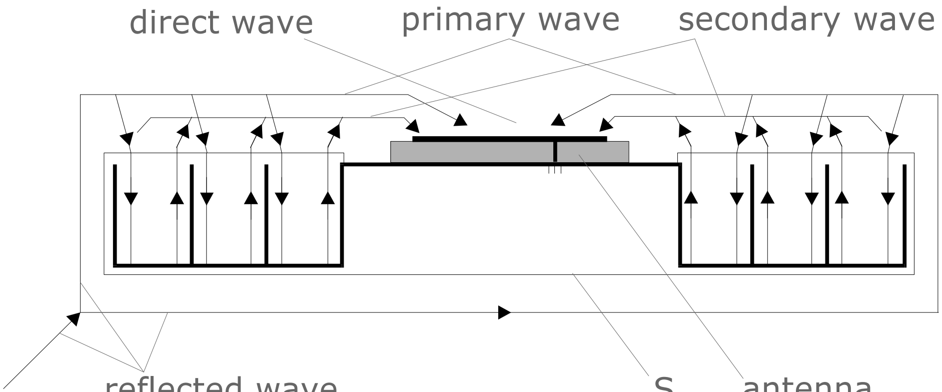
Multipath rejection choke rings — This technique works only for the multipath signals reflected from objects below the antenna. The reflected signal that hits the bottom side of the antenna can be rejected. This technique will do nothing for the reflected signals that hit the antenna on top, for example a signal that is reflected off a building above the antenna.

Fortunately most of the times the signals that are reflected from objects above the antenna have a multipath distance of more than 10 meters and signal processing techniques can mitigate them. For signals that are reflected off the ground, the multipath distance is in the order of a few meters and signal processing techniques cannot do much to address them, but choke rings can. Because of the complimentary nature of the two techniques, we can mitigate both ***"near***" and ***"far" multipaths***.

Choke Ring

A choke ring ground plane consists of several concentric thin walls, or rings, around the center where the antenna element is located. The area between the rings creates ***"grooves"***. The principle of the operation of choke ring ground planes is as follows.

The signal received by the antenna is composed of two components: ***Direct*** and ***reflected.*** The grooves have no effect on the direct signal other than decreasing the antenna gain at low elevation angles; for high elevation angles the choke ring ground plane works almost like a flat ground plane. But the grooves have much effect on reflected signal from underneath.



The electromagnetic field of the reflected signal in the vicinity of the choke ring ground plane can be viewed as the sum of a primary and a secondary field waves. The objective of the choke ring ground plane is for the primary and secondary reflected signals to substantially cancel each other and the direct signal to the antenna to remain as the dominant signal. If the amplitude of the primary and the secondary waves are equal and the phase difference between them is 180 degrees, then the two components of the reflected signal cancel each other at the antenna output and multipath is suppressed. So, a given choke ring has optimum effect only at the particular frequency that has resonance behavior.

For a given choke ring ground plane, the complete suppression of multipath only occurs at certain elevation angles; at other angles, the multipath is suppressed partially. The maximum suppression usually occurs at angles close to zenith, and minimal suppression at angles close to the horizon.

Choke rings are typically designed for one frequency. If a choke ring is designed for L1 then it has no effect on L2, while if it is designed for L2 then it has some benefits for L1. Recently, dual-frequency choke rings have been introduced that allow separate optimization for L1 and L2.

Antenna Phase Center Stability

The "electrical center" (also called the ***phase center***) of a GPS antenna is the point whose location we compute. To determine the coordinates of a point, we must co-locate the phase center of the antenna with that point. But usually the "physical center" of the antenna is positioned exactly above the point and the vertical offset is accurately measured. This vertical offset will then be taken into account when calculating the coordinates of the intended point. It is therefore assumed that the "physical center" of the antenna is the same as its phase center. This is true only in special advanced antennae designed for precision applications. The phase center of a typical antenna can change by many centimeters as the satellites' positions change. ***"Phase center stability"*** is the main characteristic of an antenna for precision applications.

In-Band and Out-of-Band Interference/Jamming Suppression

The operation of a GPS receiver can be severely limited or completely disrupted in the presence of in-band or out-of band interference and jamming signals. Most receivers filter out-of-band noise, but few suppress interference within the band.

The threat of the in-band interference and jamming signals increases daily as new communication systems are put in place and the radio frequency spectrum becomes more populated. The threat is not only from the interfering signals themselves but also from their harmonics that fall inside the GPS band.

Weak Signal/High Dynamics Tracking

Tracking satellites in an open field with no interfering signal and no partial obstruction is rather straightforward. The challenge comes when there are interfering signals that partially mask satellite signals, when there is a partial blockage that reduces the amount of signal energy that reaches the receiver, or when there are high dynamics, that increases noise. The merits that distinguish high performance receivers are in their ability to track satellites under all environmental conditions and dynamics, and in the type and quality of the measured data.

In tracking a satellite's carrier signals we have to track three main dynamics: 1) the dynamic due to the motion of the satellite, 2) the dynamic related to the motion of the receiver, and 3) the dynamic related to the oscillator (clock) of the receiver.

The motion of the satellite is the smoothest amongst the three. It can be predicted with the accuracy of a few meters per day. Even if we don't track the satellite for an hour and only rely on prediction, we will not be off by more than one meter. The motion of the receiver is unpredictable. The behavior of the clock of the receiver can also be unpredictable and abrupt, especially when it is subjected to shock, vibration, or temperature fluctuations. The change in the behavior of the receiver clock happens even when the receiver is not moving and, for example, it is sitting on a survey point.

All of the above three dynamics add together and result in a relative dynamic between the receiver and the satellite. And it is this total dynamic that the receiver must track.

There is a direct relationship between the ability to track a satellite and its signal strength. Consider the following analogy: You can easily observe a bright star in a clear night. If the brightness of the star decreases and starts to move randomly (forgive the moving star) you may have difficulty tracking it. Imagine that you are observing a weak star with a binocular. You may have no difficulty tracking its smooth motion. Now imagine you are following the same star with a binocular but this time you are sitting in a four wheel drive driven by a teenager in a bumpy road. Now you must track not only the motion of the star but also the motion of the car. If some imaginary instrument could track the motion of the car and compensate for it, you again may find it easy to follow the smooth motion of the star, perhaps even if the star became dimmer or if you drove under a tree which partially blocked your view. Even if you momentarily lost the star, you may not have much difficulty to quickly find it again when the obstruction disappears, since you can predict the smooth motion of the star.

A scheme developed by JPS (patent pending) performs the task of our imaginary instrument in the above analogy. In this scheme, the combination of all satellites is used to track the carrier dynamics of the receiver and its oscillator. Then, after the carrier of each satellite is compensated for the dynamics of the receiver and its oscillator, we have put ourselves back on a stable ground as in the above analogy. We can now track satellites under heavy foliage, or under high dynamic and interfering signals. The more satellites we track the more signals we have to add together and track the dynamics of the receiver and its clock. There are additional benefits derived from this scheme. For example, the accuracy of the output frequency signal is improved because it is tracked with the signals of all satellites, and the initial acquisition of low signal satellites is faster because the dynamics of the receiver and the oscillator are isolated from the task of acquiring and tracking satellites.

Summary

In this chapter, we learned:

- *Because of the complimentary nature of the choke ring and the signal processing methods, we can mitigate both "near" and "far" multipaths.*
- *Choke rings are typically designed for one frequency. If a choke ring is designed for L1 then it has no effect on L2, while if it is designed for L2 then it has some benefits for L1. New dual-frequency choke rings allow separate optimization for L1 and L2.*
- *"Phase center stability" is the main characteristic of an antenna for precision applications.*
- *The threat of the in-band interference and jamming signals increases daily as new communication systems are put in place and the radio frequency spectrum becomes more populated.*
- *The challenge in tracking satellites comes when there are interfering signals that partially mask satellite signals, when there is a partial blockage that reduces the amount of signal energy that reaches the receiver, or when there are high dynamics that increase noise. The merits that distinguish high performance receivers are in their ability to track satellites under all environmental conditions and dynamics, and in the type and quality of the measured data.*

Chapter 6. Radio Modems

As we discussed earlier, in real-time DGPS and RTK we transmit data from the base GPS receiver situated in a known position to the rover GPS receiver. The rover GPS receiver then takes the base data into account in order to compute its own position accurately.

Radio modems provide wireless communication between the GPS base receiver and the GPS rover receiver. We need a radio modem transmitter with the base GPS receiver and a radio modem receiver with the rover GPS receiver. When a base GPS receiver broadcasts data via its radio modem transmitter, an unlimited number of rover receivers can pick up the data via their radio modem receivers.

A radio modem transmitter consists of a radio ***modulator***, an ***amplifier***, and an ***antenna***. The radio modulator takes the GPS data from the GPS receiver and converts it to a radio signal that can be transmitted. The amplifier raises the power of the signal to a level that can reach the rover GPS. The farther the rover, the more signal power we need. The transmitter antenna then transmits the amplified signal. The power of the amplifier directly affects the distance that the signal can travel (the range) and the reliability of the communication. The range also depends on the terrain and the radio antenna setup.

The connection between the radio modem transmitter and the base GPS is via the serial ports of the GPS receiver and the radio modem transmitter. If the radio transmitter is integrated within the GPS electronics, then the connection is done internally.

A radio modem receiver consists of a radio receiver antenna and a radio ***demodulator***. The radio receiver antenna picks up the radio signal from the air and delivers it to the radio demodulator that converts the signal back to the form that can be delivered to the serial port of the rover GPS receiver.

The connection between the radio modem receiver and the rover GPS receiver is via the serial ports of the GPS receiver and the radio modem receiver. If the radio receiver is integrated with the GPS electronics then the connection is done internally.

There are varieties of radio modems in the market. The main characteristic of a radio modem is the form to which the data is converted for its transmission. ***UHF***, ***VHF***, and ***Spread Spectrum*** (frequency hopping or direct) are some examples. There are some advantages and some disadvantages to each form.

Recent introductions in GPS radio modems include the use of accurate timing of the GPS for data synchronization between base and rover(s) in order to enhance data integrity, and the use of direct and frequency hopping combination in Spread Spectrum radio to enhance communication reliability.

Government authorization may be required for using certain types of radio modems. There are international and national bodies that allocate frequency bands and issue authorization to transmit signals. In some countries, there are bands that are allocated for public use without the need for any special authorization. This is an important factor to consider when selecting a radio modem, since getting authorization to broadcast information is often not an easy task. The bands that are allocated for public use are of particular interest. The 900 MHz band in the United States and 2.4 GHz in most European countries are allowed for spread spectrum communication without any special authorization (but there are limitations on the amount of power that one can use to transmit signals).

UHF and spread spectrum radio modems are the most popular for DGPS and RTK applications. Spread spectrum radios (900 MHz and 2.4 GHz) have a range of about 20 kilometers (unless the antenna is installed in a very high location). UHF has a longer range. With a 35-Watt amplifier, a UHF radio can have a range of up to 45 kilometers, depending on terrain and antenna setup.

Summary

In this chapter, we learned:

- *There are varieties of radio modems in the market. UHF, VHF, and Spread Spectrum (frequency hopping or direct) are some examples.*
- *Recent introductions in GPS radio modems include the use of accurate timing of the GPS for data synchronization between base and rover(s) in order to enhance data integrity, and the use of direct and frequency hopping combination in Spread Spectrum radio to enhance communication reliability.*
- *It is important to consider public bands when selecting a radio modem, since getting authorization to broadcast information is often not an easy task. The 900 MHz band in the United States and 2.4 GHz in most European countries are allowed for spread spectrum communication without any special authorization.*

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