

# **PANDA**

**Program for the Aadjustment  
of geodetic Networks  
and Deformation Aalysis**

**General Information  
about the  
Software Package PANDA**

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**GeoTec GmbH  
Forschungs~Gesellschaft für angewandte  
Geodätische Technologien mbH  
Wilhelm-Busch-Straße 21  
D-30880 Laatzen  
Germany  
Tel: ++49(0)5102/915658  
Fax: ++49(0)5102/63 83  
email: mail@geotec-gmbh.de  
WEB http://www.geotec-gmbh.de**

## Software Package PANDA

The software package PANDA has been developed to design, optimize, adjust and assess 1D, 2D- and 3D networks from all areas of ordnance and engineering surveying, as well as to analyse their deformations.

**PANDA** consists of the modules:

- **Data Preparation**, accepting both terrestrial observations and GPS-baselines. Reduction and correction of data, the computation of approximate coordinates, seeking obvious observation errors.
- **Adjustment** of the terrestrial and/or GPS observations by various equations or datum values. Various tools to enlarge models and for quality assessment.
- **Deformation analysis** of 1D, 2D or 3D systems, in rigorous or approximation processes
- **Transformation of coordinates**, including best-fitting proximity adjustment

The core of the program is a graphic interface, into which the individual modules are integrated.

The modules **Deformation analysis** and **Transformation** are optional.

PANDA stores data in a relational database – the Microsoft jet-database-engine. Access to the data is realized through an ODBC-interface.

PANDA is protected against unauthorized copying by a HASP-Dongle.

### Hardware requirements:

- Personal Computer, a Pentium Processor is recommended
- 128 Mbytes RAM
- Hard drive with at least 30 Mbyte, PANDA requires about 25 MByte
- Printer, supported by MS-Windows

### Software requirements

- Microsoft Windows 95/98/Me, Windows NT 4.0/WIN2000 or WIN XP

## The User Interface

PANDA, Version 3.xx, has a completely new interface. The navigation has been simplified by using an hierarchic view of project data. All information is permanently available in its own window.

The program runs object-oriented which means that, by clicking the right mouse button, object properties can be changed or tasks can be run.

Net overviews, point lists or the results of an adjustment, deformation or transformation are presented graphically in a window. Properties of stations or observations can be modified directly by clicking on a point.

A change of scale does not influence the screen-size of the symbols and point definitions.

Coordinate lists, Epoch, Fieldbooks and Versions are each appointed a Status. The Status is presented in a graphical form, allowing easy recognition of outstanding jobs.

The scope of the visualisation can be adjusted so that, for example, the redundancy used to judge the net reliability, or the standard corrections used whilst looking for gross observation errors can be seen. Such information is shown in colour, allowing critical network components to be easily localized.

Station and observation lists can be sorted according to various criteria. For example, it is possible to sort the observations after applying the normalized adjustment, allowing gross errors to be easily localized.

Interactive network conception (including net optimization) is supported, whereby the stations and observations can be entered and immediately analysed on the screen.

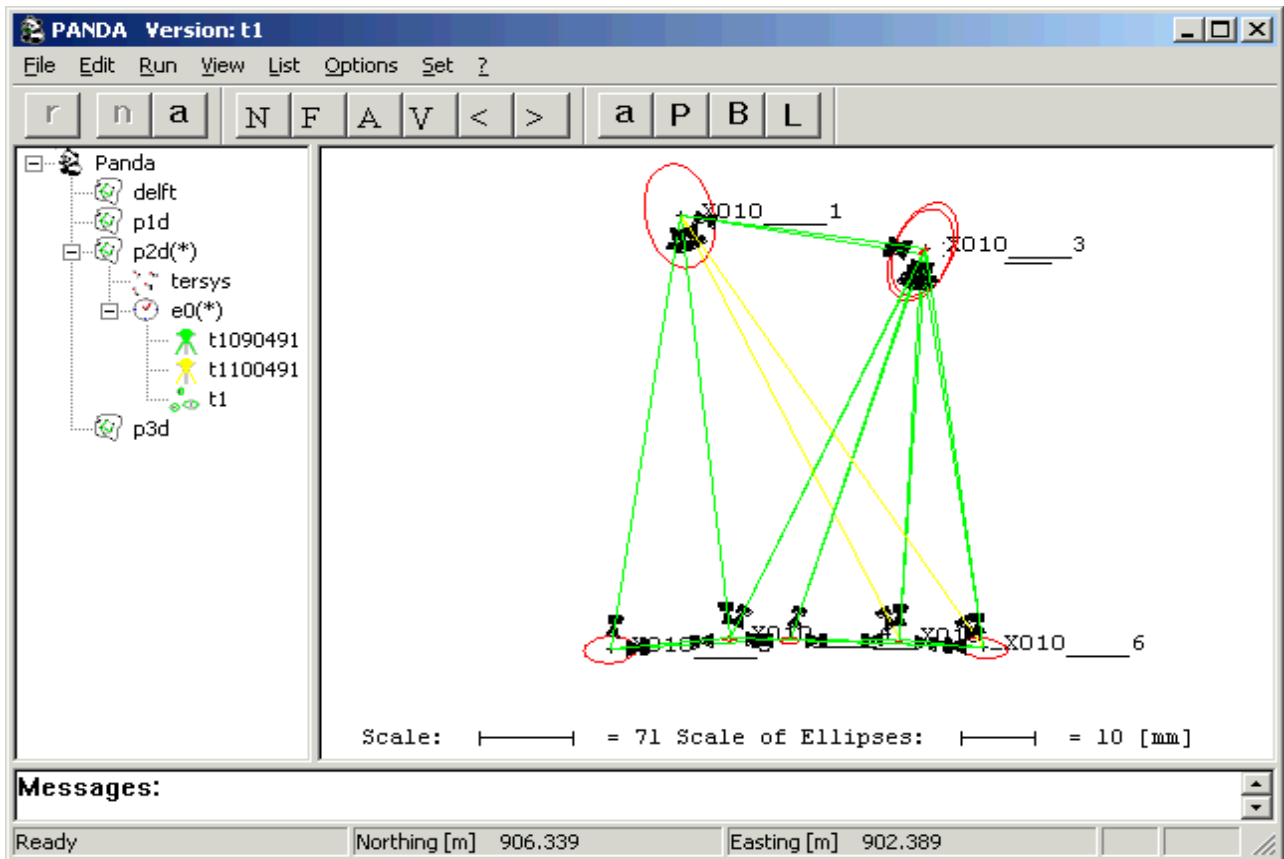


Figure 1 The User Interface for PANDA

## Data Preparation

The module Data Preparation pre-processes original terrestrial observation data (levelling data, azimuth bearings, zenith angle, slope distances) and prepared GPS-baselines, including covariance information.

The pre-processing consists of the following tasks:

- Reading raw data and creating a field book
- Evaluation and reduction of terrestrial field books
- Control of observations against obvious errors and calculation of approximate coordinates

### **Terrestrial observationprocessors:**

Raw terrestrial observation data can be input from various registration units. Automatic data flow has been implemented for the following formats:

- GSI-format by LEICA, for tacheometer and electronic levellers
- GEODAT (Spectra Precision)
- REC500 resp. M5-format by ZEISS, for tacheometer and electronic levellers

Further registration systems and formats can be implemented on demand.

### **GPS observation processors:**

- GPSurvey (SSF- and SSK-files) (TTC, Trimble)
- SKI (Leica)
- GEONAP (Geo+±)
- Geotracer
- GeoGenius (Spectra Precision)

The input of results from these processing programs is implemented as standard. Further processors can be implemented on demand.

## Reduction of Terrestrial Data

The program has several evaluating and reduction methods implemented. Their use depends upon the type of observation to be processed.

Primary instrument corrections are applied according to values found in the database, that are relevant to the instrument used. The registered values and accuracies are applied and, in the case of timestamped calibration data, the latest available calibrations found in the database are used. If there is no information available about the instrument used, the calibration will be carried out using standard values.

### **Levelling data** (precise levelling, simple levelling)

Calculation of differences in height from the staff readings, comparison with height differences between known heights. Error calculation and control.

With a precise levelling, further tests are done, e.g. controlling the staff constants, comparison of readings left / right .

### **Horizontal directions**

Normally, horizontal angles are observed and processed in sets. It is possible to process repeated observations of angles, the mean reading being computed. As far as possible, an error calculation is performed.

### Vertical angles

Vertical angles are repeated observations. They will be sorted by stations and the mean readings of the repeated observations calculated. If possible, an error calculation is performed. To calculate height differences from vertical angles, slope or horizontal distances have to be available.

For 3D processing, the vertical angles are reduced to the geodetic height level of the stations, using instrument and reflector heights. To calculate these reductions, either approximate station coordinates are taken from the list of coordinates, or the measured slope/horizontal distances are used.

### **Slope/horizontal distances**

Slope distances are repeated measurements. The distances will be sorted by stations and the mean distance calculated from the repeated observations. If possible an error calculation is performed.

For 3D processing, the slope distances are reduced to the points geodetic height levels, using instrument and reflector heights. To reduce the slope distance, either the approximate station coordinates are taken from the coordinate file, or the vertical angles are used.

<b>Corrections and Reductions</b>	<b>Dimension</b>	
	<b>2D</b>	<b>3D</b>
<b>1. Calibration Data</b>		
1. Instrument offset	yes	yes
2. Reflector offset	yes	yes
3. Scale corrections	yes	yes
4. Cyclic error correction	yes	yes

Corrections and Reductions	Dimension	
	2D	3D
<b>2. Atmospheric Adjustments</b> 1 <sup>st</sup> and 2 <sup>nd</sup> ray paths - Formulæ according to Barrel and Sears. For the Mekometer ME500, formulæ according to Owens. - Consideration of the dry and wet temperatures at the instrument station and at the target point is available (mean values)	yes	yes
<b>3. Geometrical Reductions</b> 1. Curvature and refraction 2. Incline and height reduction 3. Gauss-Krueger-Reduction, when Gauss-Krueger Approximate Coordinates (reference datum Bessel) are used. 4. Reduction of slope distances to the station's geodetic height level. The instrument and reflector axis heights must be known.  Slope distances can be reduced to the geometrical plane using known heights or the vertical angles (in an approximation method)	yes yes yes no	no no no yes

### Calculation of approximate coordinates

We have developed a new program idea for the calculation of approximate 1D-, 2D- and 3D coordinates. It is based on a combination of rigorous solutions and conventional approaches.

In order to detect gross observation errors, loops are formed and their closing errors evaluated. Approximate coordinates are determined through an L1 equalisation.

This module includes many helper tools for adjusting and correcting the input data and for running plausibility tests.

### Coordinate Systems in PANDA

The program can process coordinates in the following coordinate systems:

- **Local systems**
- local cartesian: (vertical axes parallel), local spherical: (vertical axes point to centre of sphere). Usable for small engineering nets, where they can be accepted as cartesian. Larger nets have to compensate curvature values and must, therefore, use a spherical model.
- **Global cartesian systems**
- Geocentric coordinate systems, e.g. WGS 84, useful for equalising pure GPS nets. Observation data can be entered as sets of coordinates or difference of coordinates. PANDA co-relates observation values as covariance matrices.

- **Mapping systems** for National Ordnance Survey. The mapping coordinates are transformed into, and adjusted rigorously as geocentric cartesian coordinates. The results are then transformed back into the mapping system, thus allowing widespread networks to cover several central meridians.

PANDA supports the conform Mercator and the conform Lambert projections. The following mapping systems are already defined and implemented for use:

- Gauss-Krueger (Germany, Austria, Switzerland)
- UTM
- Lambert conform (France)

Personalized ellipsoids can be defined by entering their characteristics. As to date, the following ellipsoids are defined in PANDA:

- Bessel (Germany, Austria)
- Hayford, Krassowski
- WGS 72, WGS 84
- ETRS 89

## **Transformation**

The module **Transformation** supports the Helmert (similarity) and affine transformation methods. The similarity transformation is for 2D and 3D point clusters whereas the affine-transformation is restricted to the 2D calculation.

### **Helmert (Similarity) Transformation (2D and 3D)**

This module permits the transformation of coordinates between two global cartesian systems or between two local systems of coordinates.

The scale can be pre-defined.

An affiliated **covariance matrix** of the points is also transformed.

The transformation parameters can be derived from the coordinates of at least (obligatory) **3 identical points**. **Pre-defined parameter** for the transformation can also be used.

### **Affine-transformation (2D only)**

This module allows the 2D affine-transformation between two systems.

The parameters are always defined by identical points. A 6-parameter or a 5-parameter transformation (with 2 translations, 2 scales and 1 orientation) is possible.

### **Close Proximity Fitting**

When calculating a 2D-transformation with identical points, the residual discrepancy (misclose) at the identical points can be eliminated with a close proximity adjustment. There are two calculation-methods available:

- The corrections are calculated using distance weighting. The misclose of each and every identical point is carried over to each individual netpoint. The adjusting function for the influence of the discrepancy upon the netpoint is  $s^{*-1.5}$ , 's' being the distance between the netpoint and the identical point.

- The corrections are determined by a Membran model. In this model, the point cluster is separated by a Delaunay Triangulation into triangles and, subsequently, minimized by the square sum of all the triangle-area-weighted scale modifications.

## Adjustment Program PAN

The program **PAN** allows the adjustment of multi-conditional 1D-, 2D- and 3D-networks from all fields of survey engineering and includes the possibility to calculate network-specific criteria, enabling it to analyse and optimize the networks

For the design of networks, a simulated adjustment can be carried out without real observations. The quality of the network design can be analysed according to criteria that the program **PAN** calculates.

It is easily possible to optimize the network design, simply by modifying the original network data.

### Possibilities of the Adjustment Program **PAN**

- Processing approximate coordinates from the different coordinate systems
- Adjustment of different types of observations
- Introduction of additional variables
- Different datum definitions
- Calculation of criteria to interpret and analyse networks

A further speciality of PAN is the ability to combine GPS results (coordinate differences **or** coordinates with covariance information) with terrestrial observations. The datum can be defined from either the GPS or the terrestrial system. Another possibility is the use of additional parameters to define some parts of the datum by terrestrial, other parts of it by GPS data.

### **Points**

Approximate coordinates from the following systems may be entered as data:

- local cartesian coordinate system
- local spherical coordinate system
- global cartesian coordinate system
- global geocentric system
- global projection e.g. Gauss-Krueger Projection

In global systems, the deflection of the perpendicular may be considered either by correcting the observations or by introducing it as a variable into the adjustment.

### **Types of observation**

The following types of observations can be processed:

- observed coordinates (2 D and 3D)
- coordinate differences e.g. GPS base lines (2D and 3D)
- directions
- zenith angles
- azimuths (2D and 3D)

- slope distances (3D) or horizontal distances (2D)
- height differences (1D and 3D)

For each type of observation, several groups of observations can be entered, e.g. when using different instruments. Individual standard deviations can be assigned to each group, even to each observation. By doing this, sets of observations with different accuracies can be processed together.

Special parameter can also be allocated individually to each group, e.g. varying scale corrections can be applied to the individual instruments.

For distances, a distance-dependant weighting will normally be applied.

### **Datum of the network**

With the program PAN the **datum of the network** can be defined as follows:

#### **Constrained adjustment**

A constrained adjustment will be made when there are more fixed components than the datum-defect. The datum defined by the fixpoints will be taken over into the network and the geometry of the net will be adapted. It is possible to accommodate all, or only some, of a point's components.

#### **Constraint free adjustment**

If the number of fixed components equals the datum-defect 'd', this kind of adjustment is the correct one to use. The geometry of the network is not affected.

#### **"Weak" datum**

The datum can be defined by measured coordinates. The accuracy of a point's data determines its influence upon the definition of the datum and therefore, the whole network.

The geometry of the net and the definition of the datum influence each other.

#### **Free adjustment**

Choose this kind of adjustment if the net is based upon the approximate coordinates of several datum defining points. The net will be fitted to the approximate coordinates, similar to using a Helmert Transformation. The net can be based on all points (total trace minimizing) or only some of them (partial trace minimizing). The geometry of the net and the datum-definition are independent of each other.

#### **Introduction of additional variables**

By introducing further variables to randomly selected groups of observations, it is possible to influence and modify the adjustment model of the network in several ways. A documentation of the adjusted parameter is provided.

- gyro constant (azimuths)
- unknown orientation, unknown refraction index, approximate value for the vertical angle refraction coefficient
- unknown scale of distance measurements
- unknown scale of height differences
- unknown translation, orientation and scale of observed coordinates (2D and 3D)
- unknown orientation and scale of coordinate differences (2D and 3D)

For a combined adjustment of terrestrial and baseline data, it is important to introduce additional

parameter for the baselines. The baselines exist in WGS84, but the geocentric coordinates will normally exist in the national system (in Germany, this is the DHDN) and, because these systems are not identical, the baselines have to be transformed into the national system. In the PANDA package, the transition is guaranteed by the use of additional adjustment-parameter.

### **Quality analysis of networks**

For the **analysis of the quality of a network**, the following accuracy and reliability criteria of the network - according to the requirements of many administrative regulations – are calculated by the program :

#### **For the observations**

- a posteriori standard deviations
- standardized residuals, redundancies and marginally detectable errors
- estimation of variance components for each group.
- DATA-SNOOPING is used to detect gross errors within the observations. An estimation of variances serves to control, or as a correction of, the accuracy weighting between the groups.

#### **For the stations:**

- standard deviations
- relative and specified error values and error-/confidence ellipses
- relative error or confidence ellipses (e.g. to determine the break through accuracy of underground measurements)

## Deformation Analysis program DEFANA

### General information

A deformation analysis is carried out to confirm the stability or detect the movement of stations. To attain this, a geodetic network is repeatedly measured and subsequently analysed to obtain statistically proven statements about the possible deformations. The program DEFANA has been developed to carry out rigorous or approximate deformation analyses of repeatedly measured geodetic 1D-, 2D- or 3D-networks.

### Possibilities of the program DEFANA

- The program DEFANA allows an analysis of repeatedly measured geodetic networks, in order to detect the **movement of individual points**.
- By considering the available information (covariance matrices are not available or only station-relevant submatrices are present) an approximate analysis or, if covariance matrices for both epochs are complete, (e.g. created by the program PAN) a rigorous analysis can be carried out.

The crux of the analysis is a global congruency test to show significant discrepancies between the reference stations. To avoid datum influences on the test value, a S-transformation of the discrepancies and of the corresponding covariance matrix onto the reference stations is carried out.

DEFANA has two strategies implemented:

- The **backward strategy** is based on a group of reference stations. As long as significant deformations persist within a group, one station at a time will be localized and removed. The process ends when there are no longer any significant discrepancies within the remainder of the group, or when there are only two or three points left.
- With the **forward strategy**, a group of stations that is presumably stable is used as the reference. As long as no significant discrepancies among this group can be recognized, one station at a time from a group of "potentially displaced" stations is added. The process ends as soon as deformations appear, or when all points are recognized as stable.

Criteria for the localization of stations is the greatest (backward strategy) or the least (forward strategy) relative discrepancy of the stations

Analogue to the network design, it is possible to calculate either a

- **one-step-analysis** (relative model - all stations are regarded as reference stations) or a
- **two-step-analysis** (absolute model - the network is divided into reference and object points)

A two-step-analysis is used for the control of buildings.

Other, more comprehensive models can be implemented according to user's requirements without problems.