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Using satellite methods for creating a infill geodetic networks

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Abstract. ***The purpose of this paper is to provide infill geodetic network through satellite methods on territory Salaj and Bihor counties, the localities Surplacul de Barcău and Marca and contains all existing and newly determined geodetic points, falling into a unitary reference system. To achieve infill geodetic network will use at least 4 points of geodetic network state, based on which further work will be framed in the unitary reference system. Field measurements were performed with Trimble GPS equipment with dual frequency L1 and L2 device that has a number of 72 channels and an accuracy of ± 5mm in STATIC mode, of + 0,5ppm horizontally and ± 5mm + 1ppm vertical. The recommended maximum length of bases of 120 km and Geodimeter of 600 which has measurement accuracy on directions of 3^{cc} and on distances to an accuracy of 3mm + 2ppm. Measurements for the determination of points from the main infill geodetic network were made mostly with GPS equipment and for areas where GPS measurements were not possible was used total station. GPS measurements were processed using Trimble Total Control 2.73 program of Trimble Company's. GPS data processing operation is static with intervals the takeover of 5 seconds. Compensation GPS network was performed by least squares. Trans calculation of coordinate for the new determined points were trans calculated from coordinate system ETRS 89 into coordinate system Stereographic 1970 operation that has been made using the program TransDat 4.01 of ANCPI. Coordinate reference systems used in the paper are: Coordinate Reference System Stereographic 1970 with datum Krasovski 42, based on 40 Krasovski ellipsoid and plan coordinate system Stereographic 1970 and 1975 for system altitudes Black Sea. To achieve the rises and to do the work were chosen 4 points that will thicken national network, namely: SATU, ZALU, BEIU and ORAD. Measurements were made through "fast static" process using 6 receptor dual frequencies L1 and L2, were determined 34 new points within the city of Marsa and Videle, points forming infill geodetic network, and numbered each administrative area. New points of network densification, determined by GPS measurements were marked ground concrete bollards STAS, type Feno. Rapid static method chosen to 5 seconds intervals were determined 252 bases which was stationed with GPS receivers. For verification work it was performed roading with the total station Geodimeter 600 on administrative territory Bucsani. Traverse calculation was performed using the program TOPOSYS. In terms of technical and topographical work provides accuracies required, infill and lifting points determined GPS can be used in topographic measurements.***

Keywords: 3DModel, GPS, Geodimetru, ETRS89, STEROGRAFIC 1970, TopoLT, TransDatRO, WGS 1984, Toposys.

1. INTRODUCTION

The Global Navigation Satellite Systems (GNSS) uses the technique of positioning the moving and / or static objects, at any time of day or night, 24 of 24 hours, anywhere on Earth with delivery time information real.

The Global Positioning System GPS (Global Navigation System) is a subset of the global navigation system using satellites being utilize only to provide information necessary for determining the position of points on the Earth's surface.

As GPS type systems use to us and in Europe, that use global positioning technology recall:

- NAVSTAR (*NAVigation System with Timing And Ranging)*, developed in USA by the Department of Defense and managed by the Air Force Space and known as GPS, became fully operational in 1993, with 24 active and 4 stationary satellites, respectively 31 satellites in operation;

- GLONASS (*GLObal NAvigation Satellite System)* conducted by the Russian Federation and working since 1986 with 23 satellites in operation, is the Russian version of the Global Position System, beeing designed for military and civilian use;

- GALLILEO EGNOS *(European Geostationary Navigation Overlay Service)*, is a joint initiative of the European Commission and European Space Agency in accordance with the agreement of EU transport ministers in November 2007, operational from 2013 with 2 satellites, and another 30 satellites in plan;

- BeiDou 1 *(BeiDou Navigation Satellite System)*, country of Origin – China, it is functionally from 2012 (regional) and 2020 (global) with 1 satellite in operation, and another 7-8 satellites in plan;

- BeiDou 2 *(BeiDou Navigation Satellite System)* with 35 planned satellites (GEO 5 and 4 MEO) in 2015;

- IRNSS (*Indian Regional Navigation Satellite System)*, consists of 3 satellite in GEO orbit (Geostationary orbit) and 4 on GSO orbit

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(Geosynchronous orbit) on an 36.000 km altitude with the first placement in 2011;

2. MATERIAL AND METHODS

The paper has considered increasing frequency geodetic network in the localities Suplacul de Barcau and Marca in order to conduct topographical surveys of land that will implement the project. Measurements were performed using satellite technology (G.P.S.).

Drawing network project was based on the following assumptions:

- **majority GPS measurements,** so triangulation and poligonometric terms needs a forced terminology and capabilities of this equipment to perform precision measurements, relatively constant over wide areas of work;
- **Primarily** respect of the technical rules developed by ANCPI, according to ANNEX 1, paragraph 3 of them, on achieving geodetic networks thickening.

Proposals to ensure certain similar or superior parameters for measurement and precision to those set out in relevant technical requirements (Table 1).

Table 1.Recommended execution parameters

No.	Name	Length sides [km]	Density points [pct/km]	Precision σ_{xy} [cm]
1	Geodetic network thickening (GPS)	1÷2	1÷2	±5
2	Lifting geodetic network (GPS)	0.06÷0.5	20	±5

A. The equipment used

A.1. *GPS equipment (table 2)*

Table 2.GPS equipment used

Technical characteristics tools		Operations executed and execution parameters imposed		
Equipment type	Trimble L1/L2	Main infill Network	Secondary thickening network	Secondary leveling network
Manufacturer	Trimble			
Processes	L1/L2, cod P full cycle carrier			
Number of channels	72 L1/L2			
- horizontal	±5mm + 0.5ppm	50 mm	50 mm	-
- vertical	±5mm + 1ppm	-	-	10 mm
The recommended maximum length bases	120 km	80 km	15 km	2 km

A.2. *Total stations (table 3)*

Table 3.Total station presenting

Technical characteristics tools		Operations performed and parameters of forced execution
Equipment type	GEODIMETER 600	Lifting network
Manufacturer	Geotronics AB	
Measuring directions		
- precision	3^{cc}	10^{cc}
- smallest division	1^{cc}	-
Measuring directions		
- precision	2mm + 2ppm	1:25.000 (40 ppm)
- maximum distance measurable	3000 m	700 m

B. Software used

B.1. *Trimble Total Control v2.73*

Software package produced by Trimble Navigation Ltd., used mainly for post processing of GPS measurements, it has the following main features

- The possibility of processing satellite data, acquired GPS and / or GLONASS;
- Processing of satellite data results from various positioning methods: static, fast static, kinematic, stop and go, pseudo-static;
- Display of processed entities (points, bases) graphically;
- Import, editing, management and processing of field data acquired using total stations and / or levelling tools;
- Trans-calculation coordinate (1D, 2D or 3D) between various coordinate systems;
- Compensation, by least squares method, of classical or satellite (1D, 2D or 3D) geodetic networks, independently or combined;
- How to display graphics visibility of satellites, for planning campaigns of satellite measurements;
- Possibility to import data from satellite measurements with GPS receivers, produced by: Ashtech, Leica, DSNP, Novatel, Sercel, Trimble, and Zeiss Turbo Rogue; possibility of import-export data in RINEX format; possibility to import topographic data taken with Trimble total stations;
- Possibility to import satellite data;
- The possibility to use the orthometric altitudes and a lot of global or local geoids, which was predefined in this system or defined by the user.

B.2. *TransDat 4.01*

A.N.C.P.I. software package developed, which uses a process of transformation, similar to others internationally processes, which includes a pattern of distortion of spatial data in order to maintain the integrity and topology of spatial data every datum. In conclusion, points to large distortions are not removed from the conversion, on the contrary, they are tested and included in the transformation, to describe as realistic is possible, the characteristics of each dates in which the new points are transformed.

The program aims to give users a rigorous national standard but at the same time, simply and effectively coordinate transformation between ETRS89 and Krasovski42 systems.

C. Execution data processing G.P.S. and trans calculation of the coordinates in stereographic projection system '70

Data processing was performed with TRIMBLE TOTAL CONTROL software product by 2.73 TRIMBLE NAVIGATION LTD. Accuracy imposed processing of such data is 5cm +/- 2ppm. Thickening of the geodesic network points were determined from at least 3 vectors. After processing the data using software TRIMBLE TOTAL CONTROL 2.73 were obtained subsequent offenses:

- Standard deviations errors for bases determining:

dxy = 5.7 mm, dz = 6.7 mm

- Standard deviations errors for point determining:

dxy = 4.0 mm, dz = 4.9 mm

Trans calculation from ETRS'89 system into Stereografic'70 system coordinate reference was done with software produced by transduced 4.01 A.N.C.P.I.

The transformation process takes place in three stages:

- Helmert transformation and global distortions determination of a coordinate reference system versus another, using the similarity transformation,
- Regional train modelling distortions through polynomial regression,
- Shaping local residual distortions through a rigorous compensation, and generating a distortion grid to interpolate new points.

Types of coordinates used in the application:

- Ellipsoidal coordinates B and L in sexagesimal degrees and h in meters on the ellipsoid GRS80;
- Planimetric coordinates x and y in meters, into Stereografic'70 system coordinate corresponding with the ellipsoid Krasovski40.

Coordinate reference systems used in the application:

- coordinate system ETRS89, with the datum ETRS89, based on the GRS80 ellipsoid and the ellipsoidal system (geodetic system),
- Stereografic'70 system coordinate, with the datum Krasovski42, based on the ellipsoid Krasovski 40, and the stereographic plane coordinate system 1970,
- normal system of altitudes Black Sea 1975,

The set of transformation parameters that connect and coordinate reference system ETRS89 (GRS80 ellipsoid) and national reference system S-42 (ellipsoid Krasovski 1940) are presented in Table 3.

Table 3.Helmert transformation parameters between the reference system and coordinated national system ETRS89 and S-42

Parameters	**Value**	**UM**
Translation Tx	-2.3283	m
Translation Ty	147.0416	m
Translation Tz	92.0802	m
Sc. dm=(m-1)*1e+6	-5.68907711	ppm
Rotatone Rx	-0.30924979	"
Rotation Ry	0.32482188	"
Rotation Rz	0.49730012	"

Ellipsoidal coordinates that can be processed in the program are those obtained by connecting to the national geodetic network (RGN), Class A and B, without being absolutely necessary the standing of triangulation points. Thus, the accuracy of the transformation of the new points depends largely on the current situation of the number and disposition of common points with coordinate's national territory. In our area there are a sufficient number of commonalities were able to obtain satisfactory accuracy of 10-15 cm for new points.

3. RESULTS AND DISCUSSION

Geodetic network on the territory of Salaj and Bihor counties, localities Suplacul de Barcau and Marca will contain all existing and newly determined geodetic points, falling into a unified reference system.

The item numbers newly determined will be made separately for each administrative area, starting with the number 1.

A. Project execution and choice of points

The network was stocky in these geodesic points from the national grid (Table 4).

Table 4.National geodetic network points

No.	Name	X[m]	Y[m]	Z[m]
1	SATU	701205.848	340483.372	140.863
2	ZALU	632726.277	353227.219	290.647
3	BEIU	577811.367	297506.977	202.510
4	ORAD	622250.008	267841.530	155.862

The locations were considered the following:

- location point density by 1÷2 point / km^2,
- easy access to points,
- convenient arrangement for the development and subsequent thickening of networks,
- Ensuring as is possible the visibility to other points in the network;
- Sampling period to 5 second.

In terms of geometric conformation, it will be made up of triangles as equilateral type - where GPS measurements are take place or isolated or nodal points - where measurements performed with total stations. The locations of the new points will observe the following conditions:

- Side length contour of 1÷2 km,
- Distances between points of 60÷500 m,
- Location density of 20 points / km^2 or minimum 2 points for site,
- The angles in triangles > 30^0,
- Convenient arrangement for the development and implementation of network lifting.

Especially for GPS measurements:

- Good visibility of the measurement horizon, with coverage of max. 30% over 15 degree.
- Visibility by at least another 2 points on the network infill.

Especially for measurements with total stations:

- Measured sides to be placed on the tracks as favourable work and about rectilinear,
- For each 8-10 sides to be an orientation support.

B. Materialization points

Under the rules, to materialize the main points of geodetic network will be achieved by the following scoring system: terminal pheno (STAS).

C. Measurements

The measurements for the determination of the main geodetic thickening network points will be executed mostly with GPS equipment. The conditions are aimed to be achieved for this type of work will be the following:

- Integration of at least 4 points from national network,
- Support points evenly distributed, both within the network as well as at the edge of the network,
- All new points determined from at least 3 vectors,
- Good visibility of the measurement horizon, with coverage of max.10% over 15 degree.

For areas where GPS measurements are not possible (great coverage measurement horizon with abundant vegetation or clusters of buildings), is expected for the necessary measurements using total stations. This measurement method will be also used when transmitting ground points on buildings

This measurement method will be used when transmitting ground points from the buildings.

Measurements using total stations must have the following conditions:

- Supporting to the networks points higher order already executed,
- Ends to be at least 2 guidance ports,
- The possibility of selling the breaking points and other points of higher order networks already executed,
- The maximum length of roading from 1.5-3 km in the building areas and 3-7 km in unbuilt areas,
- Azimuth observations with two sets,
- The difference between successive values in a direction max. 10^{cc}.
- closure round horizon max 15^{cc}
- Observations zenith with one series,
- The maximum error of measurement of distances 1:25.000

D. Working

D.1. GPS measurements processing

Trimble Total Control 2.73. Program from TRIMBLE NAVIGATION LTD Company, will perform work sessions, considering the following: the number of satellites to be received simultaneously from points of support and value of the PDOP site so that it is less than 4. The minimum time of observation points located at a distance of less than 4 km and more than 10 km is 25 minutes respectively more than 30 minutes for distances greater than 10 km.

Option processing GPS data is static with 5 seconds intervals takeover. In the project of GPS network, that containing points of network state and some new points, are inserted datum files observation, so when they process the new basis, the old coordinates in system ETRS 89 of the chosen points (which are references points in the project) does not will change.

After processing the project, before the compensation, it made the network quality test. In this test quality requires a precision locking triangles and polygons network of maximum 50 mm.

If the results are acceptable network will continue offsetting. If the network quality checked is not good (eg on one basic are two sessions of work, the number of satellites observed in the stationed points are less than 4 or PDOP value's is great) is deleted items affected by major errors or disable the bases with problems and reprocess.

Keep in mind that both the fixed network triangulation points and the new infill points from the stationed network to be determined from at least 3 vectors. When the test quality is satisfactory will go to compensate the GPS network.

D.2. Processing measurements made with Total Stations

After the measurements, the data acquired land shall bear the following calculations:

- Reduce distances to the reference level "0",
- Offsetting directions to the station,

- The angular non-closings of the angular routes (max. $\pm 12^{cc}\sqrt{n}$, where n is the number of station),
- Calculating the temporary coordinate of the points (X^0,Y^0),
- Calculating the temporary coordinates of points (H^0) by trigonometric levelling.

D.3. Compensation of measurements with total stations

Measurements will be offset by least squares methods, the case of indirect measurements weighted.

It will calculate the standard deviation of unit weight (σ_0) - global precision parameter and the accuracy *a-posteriors* to each measured item. To each point will be determined offset coordinates (X, Y and Z) and individual precision parameters.

D.4. GPS measurements compensation

The GPS network compensation will be made with Free Adjust option because it allows classification ambiguities and errors in the thickening network of accuracy required in processing (50 mm). When the compensation is completed, the offset coordinates and the error ellipses will be displayed for every point in the network.

D.5. Coordinate Trans calculation

The coordinates of the new determinate points, will be trans calculating from the ETRS 89 coordinate system into 1970 stereographic coordinate system. This will use one conform /orthogonal linear degree I Helmert 3D conversion line (7 parameters for the Trans calculation) being used minimum 4 points of geodetic network support.

The transformation from the ETRS89 system in '70 local stereographic systems will be done with the program TransDat 4.01 by A.N.C.P.I.

The steps of Trans calculation are as follows:

- Helmert transformation and global distortions determination of a reference coordinate system to another, using the similarity transformation,
- modeling regional distortions through polynomial regression,
- local residual distortion modelling through a rigorous compensation, and generating a distortion grid to interpolate new points.

Coordinate types used in the application:

- Ellipsoidal coordinates B and L in sexagesimal degrees and h in meters on the ellipsoid GRS80,
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Coordinate reference systems used in the application:

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- Stereografic'70 system coordinate, with the datum Krasovski42, based on the ellipsoid Krasovski 40, and the stereographic plane coordinate system 1970,
- Normal system of altitudes Black Sea 1975 (for which will be sent altitude of the new points from the national network Z points determined by using geometric levelling using EGG97quasigeoid),

E. Data processing

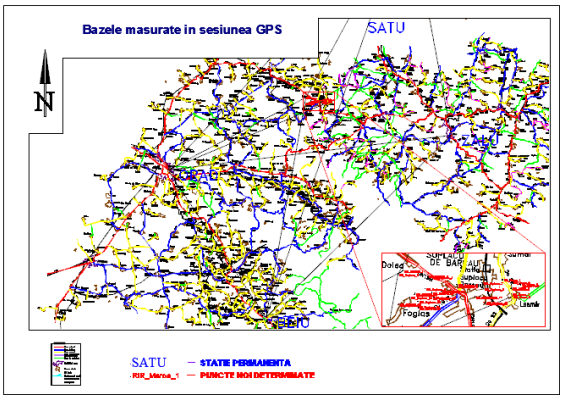

Figure 1. - Basics measured on GPS session

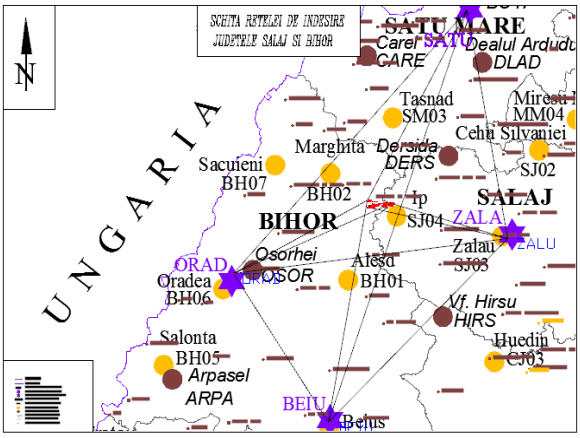

Figure 2 - Network infill scheme

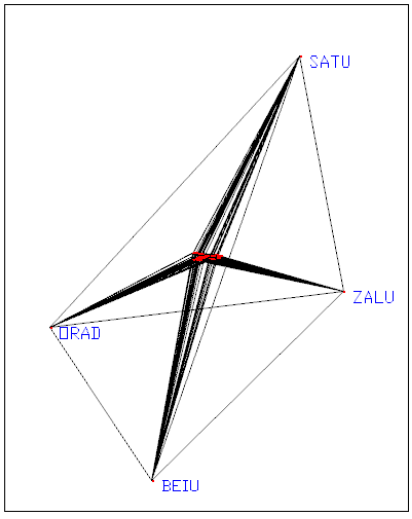

Figure 3 - Vectors scheme

4. CONCLUSIONS

The technical project was prepared on 1: 50000 map.

They were determined spatial G.P.S. 4 points of state geodetic network and were designed 34 new points of thickening and lifting numbered separately for each administrative area.

Fundamental criteria that led to the location of these points were:

- new points to be placed near roads easily accessible all year round,
- points to be located close to targets of interest for further surveying,
- avoiding obstacles materials: power lines or electric substations in GPS antenna field to a 15^0 elevation above the horizon, and avoidance of radio transmitting stations nearly,
- conservation point is assured for a long time.

Thickening points are located within the support network thereby ensuring technical conditions of determination and precise GPS data processing.

The new points of thickening network, determined by GPS measurements, were marked concrete ground terminal Stas, pheno type.

Measurements were carried out with 6 handsets G.P.S. namely: 6 receptor L1 / L2 Trimble type with dual frequency and the check points determined by GPS was carried out with the total station Geodimeter 600.

Measurements G.P.S. were carried executing one unit network. The determinations were performed by rapid static method with periods (intervals registration) chosen to 5 seconds.

The 252 basis points determinate by the points where they occupied GPS receptors having lengths between 57 m - 107 km.

PDOP's values ranged on these grounds during the stay, oscillations were due to variation position satellites. Number of observed satellites ranged between 6 and 19. All the bases were PDOP less than 4 so that its 252 bases all obtained from measurements were accepted for processing in Trimble Total Control software 2.73.

Data processing GPS measurements, calculation and compensation geodetic network of thickening and lifting were performed with Trimble Total Control software 2.73. Geodetic network was offset as a free network with *Free Adjust* option.

The Trans calculation from ETRS89 coordinate system, in stereographic system ‘70 was performed with software TRANSDAT 4.01.

Coordinate reference systems used in the application:

- coordinate system ETRS89, with the datum ETRS89, based on the GRS80 ellipsoid and the ellipsoidal system (geodetic system),
- Stereografic'70 system coordinate, with the datum Krasovski42, based on the ellipsoid Krasovski 40, and the stereographic plane coordinate system 1970.

Traverses calculation was performed with the software company's Toposys GEOTOP.

The results of verification presented in the appendix to the internal review, allow you to appreciate the good quality of determinations G.P.S. from the paper presented at check in. The 1970 stereographic coordinates determinate of the points of verification are shown in the tables below on line 2 of work checked as follows:

Table 5.Coordinates

Point	*Determination*	*X(m)*	*Y(m)*
RIR_ SUPLACU _17	1	642554.411	314329.004
	2	642554.402	314329.025
RIR_ SUPLACU _18	1	642547.618	314045.154
	2	642547.602	314045.141

From a geodesic - topographical technical point of view these work provide accuracies required by technical norms. Thickening and lifting points determined by GPS can be used in the topographic measurements that will be done to raise land belonging localities: Marsa and Videle.

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