National Report of Bulgaria

G. MILEV[1], M. MINCHEV[2], K. VASSILEVA[1], T. TASHKOV[3], G. PETROV[3], G. VALEV[4], T. BELJASHKI[5]

Abstract

The main activities on the EUREF have been outlined. The operation of the permanent station, near Sofia, introduction of the coordinate system BGS2000, regulations and their applications, National GPS network, maintenance and use of the EUREF points, combined geodetic networks and the related works in Bulgaria have been shortly presented. The activities on DGNSS and the project EUPOS as well as the preparation of the National levelling network to be included in the European height system (EVRS). The works on the projects UNIGRADE, CERGOP-2, national cadastre and other EUREF activities have been outlined.

1. General

At this stage the EUREF implementation in Bulgaria has been determined by the transition of the economic, the realized necessity of it by the government and the leading specialists in our country. It is in conformity with resolutions of the EUREF symposia, needs and possibilities, international cooperation, availability of specialists and their professional orientation etc. The EUREF implementation is mainly related to the National Geodetic System BGS2000, regulations, National GPS network, development of a system of permanent GNSS stations and application of DGNSS, integration of the National levelling network with the European one, and preparation for introduction of EVRS, National gravity system and geoid, realization of the combined geodetic network, cadastre problems, geodynamic investigations etc. [12], [19], [22], [23], [29].

2. Permanent station and regulation base

2.1. Permanent station

Bulgaria has been integrated to the EUREF network of permanent GPS stations (EUREF Permanent Network – EPN, [6]) with the Permanent GPS station located near Sofia (SOFI) in May 1995 by the active cooperation of the Bulgarian institutions and the present German Federal Office for Cartography and Geodesy - BKG. The equipment and the operation of the Permanent GPS station are an achievement of the joint work [18], [21], [33]. The actual starting of operation of the station in the EPN was realised on 19.05.1997 at 10:00 UT.
At present SOFI is operating as a control station and an operating center of EPN. Hour and daily data files are transferred to the regional data center "IfAG" in Germany. Hour data files contain only the registrations of GPS observations and daily data files – additionally the meteodata as well. The number of operation breakdowns and their duration presents the stability and reliability estimation of the station (Table 1, Fig. 1).

[1]Central Laboratory of Geodesy-Bulgarian Academy of Sciences, Acad. G.Bonchev Street, Bl. 1, 1113 Sofia, Bulgaria
[2] University of Mining and GeologyGeoinformation Company, Ltd., P.O.B. 132, 1618 Sofia, Bulgaria
[3] Center of Geoinformation Supplying - Ministry of National Defense, 34 Totleben Blvd., Sofia, Bulgaria
[4] University of Architecture, Civil Engineering and Geodesy, 1 Hr. Smirnenski Blvd., Sofia, Bulgaria
[5] Research in Geodesy and Photogrammetry Ltd (NIGIF)

Table 1: Breakdowns of the Permanent station SOFI, 1997-2002

Year	DOY with breakdowns	Total	Cause
1997	273,274	2	
1998	85, 109, 113, 148, 165, 168, 183-185, 216, 217, 221, 235, 243, 244, 251-254, 257-264, 320-325, 364	34	Power failure, Telephone cable disconnection
1999	22, 206-208, 231, 244, 253, 261, 262, 265, 291, 292, 294, 314, 315, 326, 331, 357-360, 364, 365	23	Power failure, Telephone cable disconnection
2000	18, 28, 29, 30, 41, 42, 74, 79, 91, 120, 129, 134, 135, 233, 236, 258, 268, 270, 271, 311-314, 327, 330-335, 366	31	Power failure, Telephone cable disconnection
2001	1-90, 100, 101, 105, 107, 118, 338, 344-349, 360, 364	105	Upgrade of GPS receiver, replacement of telephone cable
2002	275, 276	2	

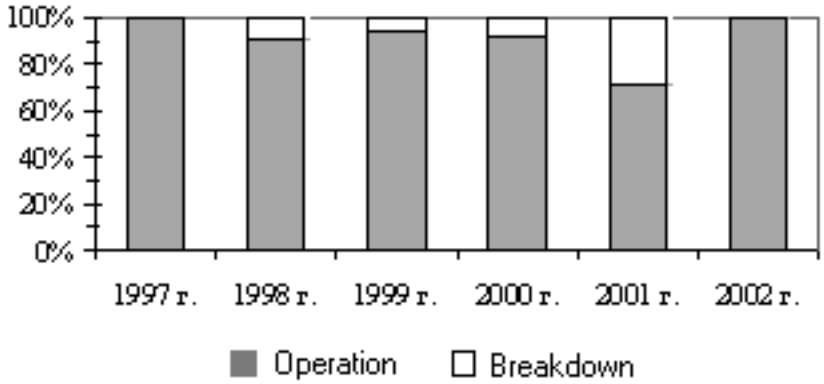


Fig. 1. Operation reliability of the Permanent station SOF**I**

The quality of the permanent station SOFI is determined by the coordinate differences (in position and height), obtained from 6-parameters Helmert transformation (Fig. 2). The week solutions are compared with the annual solution which are combinations of the week solutions from several years. Combination of the week solutions has been performed in ITRF97 (epoch 1997.0) with the option "ADDNEQ" of the Bernese software, V4.2. For definition of the system the coordinates and the velocities of the following EPN stations have been used: GRAS, GRAZ, HOFN, JOZE, KOSG, MATE, METS, VILL, ZECK. For about of 6 years of operation of the station SOFI systematic changes in position (north and east) of about 20 mm have been occurred and in height (up) – within 30 mm for a period of 1 year.

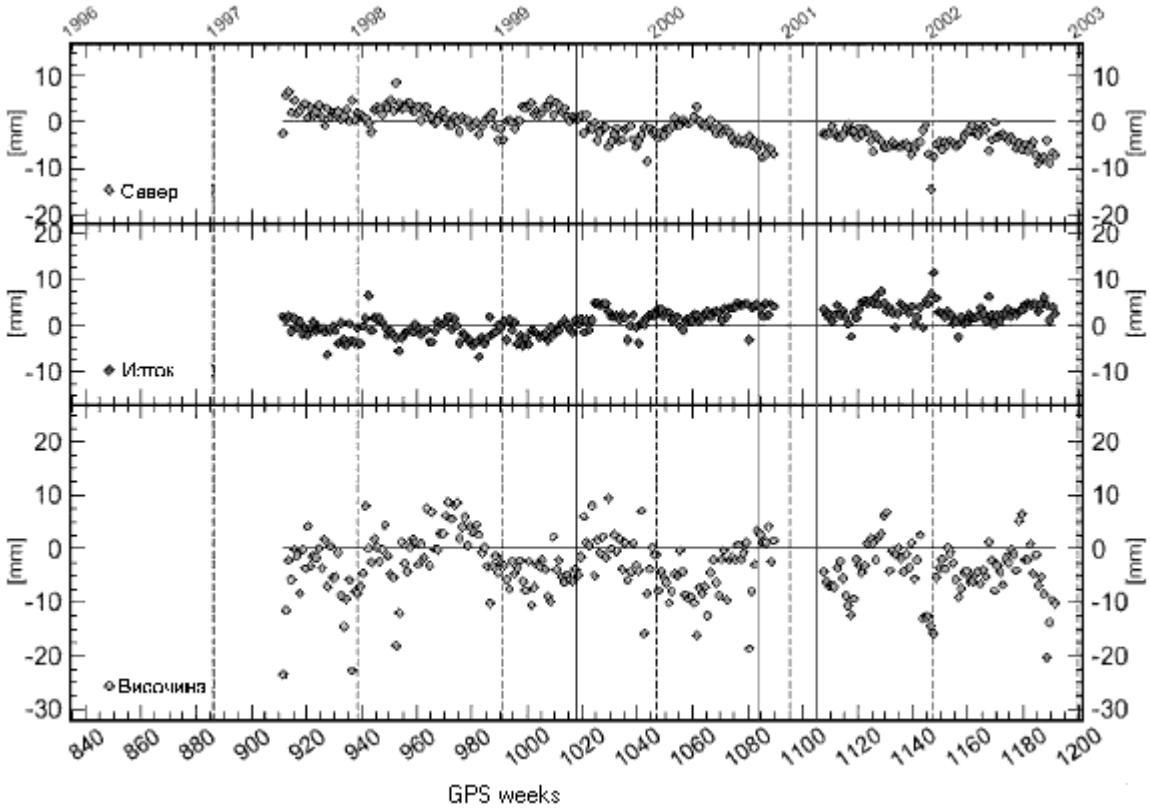


Fig. 2. Comparison of the solutions obtained for the permanent station SOFI

2.2. Regulations

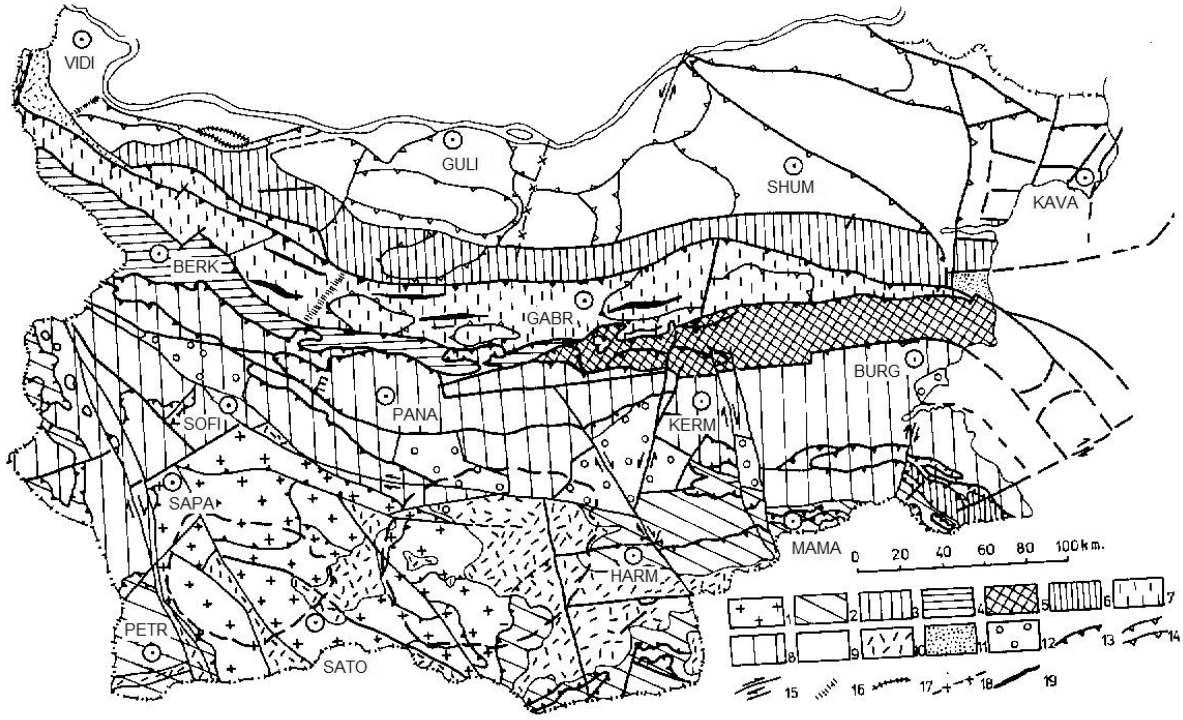
The introduction of EUREF in Bulgaria has been regulated with an Act of the Council of Ministers of the Republic of Bulgaria since 04.06.2001 [1]. This Act defines the geodetic system for the territory of Bulgaria named "Bulgarian Geodetic System 2000" (BGS2000). According to the governmental document, BGS2000 is materialized by a network of geodetic stations and services, and serves as a base for producing and maintenance of the cadastral map of the country. The Ministry of regional development and public works (respectively "Geodesy and Cartography" Department) is responsible to implement this Act and to publish regulations for its application.
A project for regulations is worked out. The basic parameters of the system, map projection and related mathematic tools, gridding and nomenclature of the large-scale topographic maps, basic requirements for establishment of the control GPS network as a real step of the introduction of BGS2000 as well as the methods for transformation of geodetic and cartographic products from the available system "1970" into BGS2000 are given in the project [32]. Editing and preparing for printing of regulations are in progress.
The came into operation in 2002 law for the qualified information eliminates the restrictions on dissemination of geodetic, cartographic, cadastral and other similar information. In this way a common regulation base for introduction of BGS2000 is provided. Hence, the required preconditions for an adequate application of the modern geodetic technologies, development of the market of geodetic products and services and for differentiation of regulating duties of the specialised governmental bodies will be also provided.
Entirely new and not yet regulated technologic element are GPS data from permanent stations distributed by mass media, Internet or by cellar phones. The frequencies used, the authorized type

devices (modems, transmitters etc.) are coordinated with the Committee for telecommunication regulation. However, it is necessary to be clarified the status of this information and the respective rights and responsibilities of its providers and users.

3. Maintenance and use of EUREF points on territory of Bulgaria

3.1. General information and applications

The maintenance and use of EUREF and the points of it on the territory of Bulgaria is many-sided and all over the country.
The EUREF was officially introduced in Bulgaria with 7 points accepted at the Ankara symposium in 1996 in class B. One of them is a permanent station. Actually, the EUREF points are 15 as their coordinates are results from the combined processing of two GPS campaigns in 1992 (7 points) and in 1993 (15 points), and they define BULREF.The 15 points are shown on figure 3 on the background of the tectonic map of Bulgaria [5], [21].



Legend: A) Elements of the Block structure (1- Rhodope Pre-Alpine Basement; 2- Moravides, East Rhodopes and North Strandjides; 3- South Moezian Peri-Platform Zone; 4- Stara-Planina Unit; 5- East Balkan Unit; 6- South Strandja; 7- For-Balkan Unit; 8- Sredna Gora Neoautochtonous Zone; 9- Moezian Platform; 10- Volcanic-Sediment formation of the Trace Rift (Neoautochtonous); 11- Lower-Kamchia and South Karpatian Back Subsidence; 12- Post-Collision Neoautochtonous). B) Linear elements (13- Nappe fronts; 14- Structure of the Moezian Platform; 15- Faults; 16- Kriptofaults; 17- Geophysical passages; 18- Litosphere faults; 19- Fault Axes of the For-Balkan)

Fig. 3. EUREF points on the territory of the country

The average distance between the 7th EUREF points is 100-150km, and between the 15th points – 40-60km.

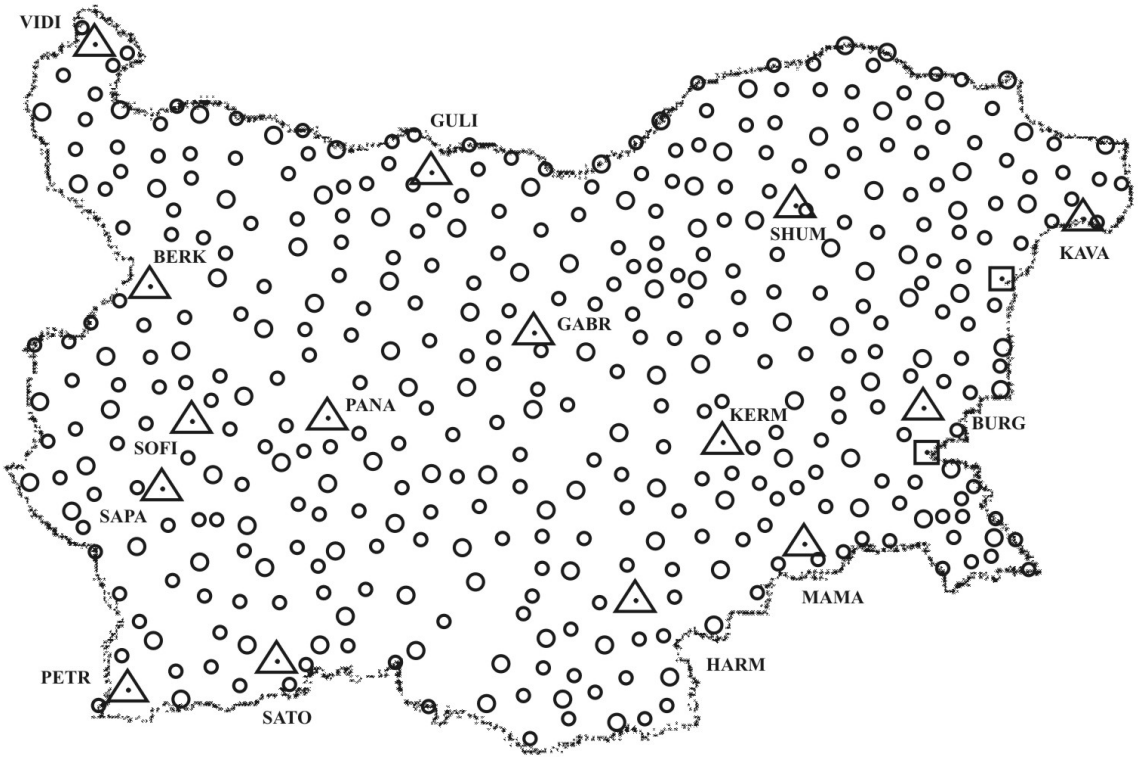
A coherence of the points and EUREF database exists.
Meanwhile the connection of the BULREF points with the state geodetic and levlling networks has been realized. The parameters of transformation between the state coordinate systems and the ETRF89 have been obtained as a program MTSTrans for Windows has been developed. Except the obtained relations between the systems a digital model for the height differences between the Baltic normal heights and geodetic heights above the GRS80 ellipsoid for the territory of the country has been applied. As the European system ETRF-89 and the World geodetic system WGS-84 are very close so the software could be successfully applied to other cases as well.
The strategy of maintenance of the EUREF network is based on the mentioned in section 1.2 regulations. Along with that the EUREF points are in a full value use. The markers are periodically controlled. The users of EUREF points have been informed about its development and application – specialized journals, symposia and conferences, and proceedings of them as well as other ways of information. There are specific plans for further applications and development of EUREF like the projects and the realization of the national control GPS and EUPOS (European Position Determination System) networks.
GPS measurements were used mainly for reconstruction of the state geodetic points of 3rd and 4th order after 1990 without changing the character of the State geodetic network (SGN) as a classical geodetic network (Fig. 4) [24], [31]. Replacement of the horizontal measurements by the more effective GPS measurements without up dating of the principles for establishment of SGN leads to the insufficient use of the GPS data information. Using a lot of identical points transformation parameters are derived and they have been used for transformation of GPS results into the State coordinate systems.

△ - BULREF points, • • - 1st and 2nd order points, ◉ - GPS points

Fig. 4. GPS determinations in the State geodetic network

3.2. Control (national, state) GPS network

The points of the BULREF have been accepted as zero order points of the control network of the country on which will be based the National GPS network.
A provisional project for a control (national, state) GPS network has been proposed where the continuity of the old and new networks is combined with the ambition to achieve maximum conveniences – access, respective conditions for conventional and GPS measurements, high precision in position and height (table 2) [8], [10]. Recognition of the selected points (fig. 5) and accomplishment of necessary construction and repair works are in process.



△ - BULREF points, ⊡ - EUVN-97 points; ○, ○ - 1st and 2nd order points of the State geodetic network

Fig. 5. Project for Control (National) GPS network

It is expected the measurements of the network and data processing to be done during the next two years and the necessary requirements for the introducing of BGS2000 will be fulfilled, and to come out of the stagnation of the state geodetic works.

Table 2. GPS network points

Points of the existing network			**New points**		**Total points**
1st and 2nd order points	3rd and 4th order points	LGN*	Gravity points	Other points	
134	249	9	47	4	442

LGN* - local geodetic networks.

4. DGNSS and EUPOS in Bulgaria

In many counties all over the world and specially in Europe multi-functional differential GPS, respective DGNSS systems and services have been established such as the Satellite Positioning Service (SA*POS*®) in Germany. Its multi-functionality and efficiency, especially for specialised applications in geodesy are realized [34]. The necessity and the expedience of establishment of a SA*POS*® analogue - DGNSS in Bulgaria is already realized and active work on its establishment has been done [16], [17], [20], [28]. All that is accomplished on the base of the established cooperation between the Bulgarian geodesists and the Senate of Berlin. As a result, a pilot project of *EUPOS* for Sofia has been proposed. The realization of the project involves DGNSS service for transmission of corrections, which will be received by different media – VSW/RDS, GSM/GPRS and Internet.

In 2002 it was developed the project *EUPOS* with the active participation of Bulgaria. It appears as a regional development for Europe of the satellite system for positioning SA*POS*® in Germany. The project *EUPOS* is an initiative for establishment of a unified DGNSS base infrastructure for Central and Eastern Europe. It is a multifunctional regional application of DGNSS and involved 15 central and eastern European countries. Networks of active reference stations will be established on the base of the common reference system ETRF-89, unified data formats and international standards with an accuracy of 1-3m up to 2cm in real time and higher accuracy in post processing [4], [14]. Actually, the mentioned pilot project for Sofia occurs as such a project for *EUPOS* as well.

5. Combined geodetic network and its realization in Bulgaria

The tendency and the concept for complex consideration and establishment of combined control network in the region of Europe find a response in Bulgaria as well. It is based on the following principles for establishment of the control networks:

- Collocation of the points from classic leveling and gravity networks with the control GPS network
- Establishment of combined (united) networks which points are absolute gravity stations, leveling benchmarks and permanent GPS stations.

The first principle is grounded in the establishment of the National GPS network as it is presented in section 2.2.

The second principle has been taken into account in the realization of *EUPOS,* CERGOP2 project and National gravity system for Bulgaria (Post UNIGRACE) [4]. For this purpose a respective project taking into account the mentioned projects and the available EUREF permanent station near Sofia is in progress.

6. European Vertical Network

Realization of the European Vertical Reference System (EVRS) on the territory of Bulgaria is determined by the successful inclusion of the National Levelling Network along with a supplementary information into the database of UELN. For this reason, a preparation of the data of the 1st order-levelling network of the country has been carried out according to the requirements [18]. Special preparation is going on for realization of the levelling connection between the neighboring countries and primarily with Romania for UELN connection. The territory of Bulgaria is included in the project of EUREF - European Vertical Reference Frame (EUVN) by three points [11]. Two of them are special pillars for GPS measurements located at the Black Sea

coast, near the tide gauges respectively in Burgas and Varna. The third point is the pillar where the antenna of the permanent GPS station is installed, near Sofia. The gravity values of the three points have been determined. Their normal heights have been also determined as the levelling connection between the pillars at the Black Sea coast and control benchmarks of the tide gauges points has been realized. The monthly values of the mean sea level for the period 1997-2000 have been determined [18].

7. Activities related to the EUREF

Bulgaria actively participates in the works within the framework of IAG Section V "Geodynamics", the program "Geodetic and Geodynamic programs of the Central European Initiative (CEI)" and in the Central European Regional Geodynamic Project of the 5th Framework program of EC.

Since 1996 Bulgaria has been associated to the Central Europe Regional Geodynamics Project (CERGOP) taking part in the CEGRN'96 and CEGRN'97 GPS campaigns with two EUREF stations. It is expected another two points to be involved in future campaigns [15].

A project under the name CERGOP2 is financed within the framework of the 5th Framework Program of EC in 2003. Working groups for Geotectonic analysis of the region of Central Europe have been established within the work program of the project. A new special group "Geodynamics of Balkan Peninsula" has been also established. The first contribution of this group was the organized symposium "Geodynamics of Balkan Peninsula" within the 3rdBalkan Geophysical Congress 24-28 June 2002, Sofia, Bulgaria.

For the complex investigations on the project every two years a specially established GPS network CEGRN has been measured. The Bulgarian participation in the project is on the basis of four points of the EUREF. During the time 16.06-21.06.2003 a GPS campaign will be carried out according to the project and points from Balkan Peninsula will be involved. Some of the points are also EUREF points.

In co-operation with the Massachusetts Technology Institute a network of 18 GPS stations, spread uniformly all over the country was established. The measurements were carried out during the East-Mediterranean GPS Campaign, September 1996, with 4 Trimble 4000 SSI/SSE receivers in 72 hours continuous sessions.

Two weeks later, two of these stations and four tide gauge sites at the Black See, were involved in 10-days GPS measurements within the Greek Arc geodynamic project. The tide-gauge sites were also measured in 1994, with Wild System 200 receivers. In 1997, the same sites were occupied again to take part in the EC SELF II project.

In 1997, a local geodynamic network of 22 stations in the western part of the country was observed using Trimble 4000 SSI/SSE receivers. A connection with the network measured in 1996 has been provided in this way.

Concerning seismic investigations observations at two existing networks have been performed since 1990. The Kresna network (17 stations) is situated near the epicenter of one of the strongest earthquakes in Europe this century (1906, M 7.8). The Chirpan network (19 stations) covers the region of the destructive earthquakes occurred 1928.

Geodynamic investigations on the territory of Bulgaria and the neighboring countries have been carried out on the base of projects funded within the National Council "scientific Investigations" at the Ministry of Education and Science.

Three absolute gravity stations have been established on the UNIGRACE projects of the COPRNICUS program of EC and a National gravity system is being developed [27]. Bulgaria is involved in the project Unified European Gravity Network 2002 (UEGN2002) as well.

Improvements of the national geodetic network on the base of GPS and EUREF as it is mentioned in section 2.1 are going on in pursuance of the works on the project for cadastre and property register of Bulgaria [4].
Along with these activities other ones are also going on related to the reinstate of the property, geodynamic investigations in selected regions of the country, GPS in engineering surveying and many others.

8. Conclusion

The follow-up realization of the EUREF on the territory of Bulgaria after its introduction is an unquestionable fact. The activity in this direction is going on according to the possibilities of the country. The EUREF and IGS permanent station near Sofia operates without problems. Regulations exist. The EUREF points were and they are used in a variety of applications. That concerns the control network of the country, cadastre, geodynamics and many others. It is worked on the application of the DGNSS and the combined networks of the country as a regional element and for whole Europe. Important activities related to the EUREF are also going on. However, the objective necessity requires the rate of the realization of EUREF to be more intensive.

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