Trends of Development of the Lithuanian National Geodetic Control

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1. Introduction

Since 2001 the main geodetic activities in Lithuania are supervised by the National Land Board under the Ministry of Agriculture. The efforts are directed to improve the main components of geodetic control: GPS, Vertical, Gravimetric and Magnetic networks.

Lithuanian National GPS network already finished. It consists of three orders GPS sites and totally includes over 10000 points [1–5].

Since 1998 the development of Lithuanian National Vertical network is going on. Until 2002 about 40% of job is done [5, 6].

In 2001 the development of Lihuanian National First Order Gravimetric network was finished. Network is based on three absolute gravity points. There are 51 gravity points in the first order gravimetric network. Totally 112 baselines were observed using from three to six *La Coste & Romberg* gravimeters.

Since 1999 the magnetic field observations were started at six points in Lithuania. Declination of magnetic field, inclination and vector of intensity were determined. Observations were repeated in 2001.

In 1996 the Kyviðkës Calibration Baseline was established to meet the needs of calibration of EDM instruments in Lithuania. The high precision EDM instruments used in Kyviðkës have been calibrated at the Nummela Standard Baseline. It complies with the accreditation criteria for calibration laboratories as laid down in ISO/IEC 17025:1999.

The International Institution for the History of Surveying & Measurement of the International Federation of Surveyors (FIG) has a goal to perpetuate F. G. W. Struve's Geodetic Arc as UNESCO World Heritage Sites. Lithuanian National Land Board under the Ministry of Agriculture and Institute of Geodesy of Vilnius Gediminas Technical University have suggested to perpetuate 2 Struve's geodetic arc points – Meškonys (Meschkanzi) and Gireišiai (Karischki), the points of National Geodetic Network. Suggestion was supported by Commission for National Heritage of Lithuania and Department of Cultural Heritage of Ministry of Culture of Lithuania.

2. National Vertical Network

The main geodetic activities of Lithuania since 1997 were related to the establishment of National Vertical Network [5, 6].

There is no geodetic vertical network in Lithuania, which would fulfill modern requirements. One part of the network is levelling network – which is too old and does not fulfill the demands of the sovereign state. Therefore establishment of the modern geodetic vertical network is a must.

The goal of the Lithuanian geodetic vertical network establishment is the determination of geopotential heights of the points and creation of height reference network for the country. The geodetic vertical network should implement unified system of heights in the territory of Lithuania and guaranty reliable connection with other European height systems. Geodetic vertical network should be continuously updated for the purpose of heights and their accuracy determination.

Design of the first order geodetic vertical network is done by taking into account already existing first and, partly, second order levelling lines. There are five closed polygons in the network (Fig 1). Perimeter of the network is ca. 1900 km.

The main Lithuanian GPS points as part of EUVN and BSL networks are Vilnius, Šiauliai and Molas. They are included into the first order geodetic vertical network. Existing reference benchmarks of previous levelling, which reach 1.8 meter bellow ground surface and suitable wall benchmarks will be included. Average distance between points will be 1.5 km and maximal 2.5 km. New monumentations of benchmarks will be established at least every 6 km (except of towns and settlements). Reference benchmarks will be built at every 40-60 kilometres. Benchmark satellites will be built in 50-150 meters from reference benchmarks. Ground benchmark construction is suitable for the GPS observations. Location of the reference benchmarks and ground benchmarks is selected at the sites suitable for the GPS observations.

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Fig. 1. National Vertical Network

Digital levels NA 3003, precise invar levelling staffs with temperature sensors or with thermometers measuring temperature of invar strip were used for measurements.

Calibration of staffs and tests of precise levels should be done at the stationary calibration base of Finnish Geodetic Institute before the observation season starts. Intermediate calibration of the staffs could be done in the field by control meter during the season of observation at least once in two months.

Ground benchmarks are co-ordinated by dual frequency GPS receivers from the National GPS network of Lithuania.

Progress of Lithuanian National Vertical Network development is shown in Fig 1.

By developing Vertical geodetic network of Lithuania along with the establishment of EUVN and by connecting it to neighbouring countries vertical networks, the new network will be tied up to the unified European height system and integrated into the European geodetic network.

3. National First Order Gravimetric Network

Lithuanian National First Order Gravimetric Network was established and gravimetric reference was evaluated by support of Danish, Polish and USA specialists in 1998-2001 (Fig 2.). It based on absolute and relative gravity observations. Absolute gravity observations were performed by Finnish Geodetic Institute (J. MÄKINEN) in 1994 in three points VILNIUS, PANEVËPYS and KLAIPËDA by ballistic gravimeter JILAg–5 [7]. Gravity value was determined with 5–7 mGal accuracy. In this way modern high accuracy IGSN 71 system reference for gravity field research was created. For extension of IGSN 71 system gravimetric reference for the whole Lithuanian territory the first order Lithuanian National Gravimetric Network of 51 point and 112 lines was designed [8–10]. Absolute gravity points have been chosen as reference for the network. The Lithuanian and Polish National gravimetric networks were connected by relative gravimetric observations between sites GIBY and LAZDIJAI.

The gravity points are very often chosen in churches or other official buildings close to the motor-road system, in order to combine lasting existence with easy access and quick transport. The gravity points located on the steps of the churches were equipted with the metal marks.

First order network observations have been performed in 1998–2001 by collaborating with Warsaw Geodetic and Cartographic Institute specialists. The relative gravity observations in the network have been performed using 3–6 *LaCoste & Rmberg* gravimeters G-1012, G-1036, G-1078, G-1084 of Warsaw Geodetic and Cartographic Institute and G-191, G-192, G-193 of NIMA. Each line of the network was observed three times.



Fig 2. Lithuanian National First Order Gravimetric Network

The gravity observations in the Lithuanian precision gravity network have been adjusted by least squares method based on reduced gravimeter readings and the adopted absolute gravity values. It appears that the absolute values agree very well with the relative observations, and the that the general accuracy level of the adjusted gravity values of network points does not exceed 5,3 : Gal. The aposteori standard deviation of a single line was estimated to be 4,9 : Gal. Detailed describtions of all Lithuanian National First Order Gravimetric Network points are given in catalogue (Fig 3).

A newly established gravimetric network is a reference for new gravimetric and geodetic works and further gravimetric field and geodynamic research.



Fig 3. A catalogue page of gravity point

4. Investigations of the magnetic field

The magnetic field of the Earth tends for constant changes in time. Data of geomagnetic field should be periodically updated in the magnetic, topographic or navigation maps. Special attention should be paid to declination, because it is the main element used for solution of orientation problems in geodesy.

The need for updating magnetic field data has increased during the last decades. Data is needed not only for geodesy and mapping, but also for search of natural resources, military applications and navigation.

Complex observations of Lithuanian territory magnetic field with determination of at least three magnetic field parameters

have been performed 6 decades ago. Some magnetic field research was carried out during the last decade. New observations were done in a few sites only. For research of the whole territory magnetic field it is necessary to create a reference for determination of magnetic field elements variation changes. At the reference points it is necessary to perform regular observations and determine precise values of magnetic field elements for certain epoch.

So six geomagnetic points have been projected for Lithuanian territory in 1999 according common activities program of Institute of Geodesy and Cartography, (Poland), Institute of Geology (Belarus) and Institute of Geodesy of Vilnius Gediminas Technical University (Lithuania) (Fig 4).



Fig 4. Location of secular variations stations in Lithuania

Together with 12 points in Belarus and 19 points in Poland, this should create homogeneous network for observations of the secular variations in the north-western part of the Precambrian Platform of Eastern Europe. Magnetic field observations have been performed for secular variation research in 1999 and 2001. The survey was performed by specialists of Institute of Geodesy (Poland) and Vilnius Gediminas Technical University (Lithuania). Results of research are shown in the Table 1.

Table 1. Mean annual values of measured magnetic components at secular variation stations

No.	Point	D • ' "	Õ"	F nT	D Õ"	Õ"	F nT
		1999			2001		
1	ŽIEŽMARIAI	5 57 55	69 45 33	50498.5	6 09 32	69 47 03	50570.3
2	DUSETOS	5 39 27	70 27 49	50975.1	5 50 22	70 28 58	51053.2
3	PAROVËJA	5 31 29	70 41 49	50070.1	5 42 45	70 43 47	50145.1
4	ŠAUKOTAS	4 04 51	70 18 06	49938.5	4 16 04	70 19 43	50013.0
5	TRYŠKIAI	4 57 48	70 39 49	50207.1	5 09 09	70 41 53	50778.5
6	ŠYLIAI	4 24 17	70 42 15	50815.0	4 36 19	70 44 00	50890.3

Results of research show, that elements of magnetic field through two years changed for declination 11,39', for inclination 1.68', for magnetic field force intensity 74,35 nT.

5. Kyviðkës Calibration Baseline

The Kyviðkës Calibration Baseline was established in 1996 to meet the needs of calibration of electronic distance measurement (EDM) instruments in Lithuania. It consists of six observation pillars in line at 100, 360, 1 120, 1 300 and 1 320 m distances from the first pillar (Fig 5). The difference in altitudes along the baseline is less than 6 m. The location is homogenous grassland at the airfield area of Kyviðkës Darius and Girënas squadron airport. In year 2000 one more observation pillar was constructed at the other side of the airfield, expanding the original baseline to a multipurpose test field for GPS measurements, theodolites, total stations and other surveying instruments.

The baseline was first measured with high-precision EDM in June 1997 in cooperation between the Vilnius Gediminas Technical University (VGTU) and the Finnish Geodetic Institute (FGI), as reported in [11]. A remeasurement was performed in October 2001, again in cooperation between the same two parties. The FGI has a long tradition as the National Standards Laboratory (NSL) for geodetic quantities (length and acceleration of free fall) in Finland, and since 2002 it is a member in the Mutual Recognition Arrangement (MRA) of the Metre Convention [12]. The procedures in the NSLs of the FGI fulfil the general requirements for the competence of calibration laboratories (standards ISO/IEC 17025:1999 and ISO 9001:2000). Also in the VGTU similar work for standardization and acknowledged quality is a topical matter.



Two high-precision EDM instruments with a long-term control and calibration history were used in the measurements. The Kern Mekometer ME5000 has a $\pm(0.2 \text{ mm} + 0.2 \text{ ppm})$ measurement accuracy. The same ME5000 of the Helsinki University of Technology was used in Kyviðkës in 1997 and 2001 (Fig 6).



Fig 6. Kern Mekometer ME5000 on the pillar No. 7

Prism reflectors were used at target points. The integrated equipments (Kern or Wild) were fully compatible giving no cause for eccentricity corrections. Forced centering method in Kyviðkës is simple and practical: instruments are centered on observation pillars with sufficient accuracy with 5/8 inch fixing screws through the pillar top plate.

Baseline lengths and additive constant were solved in leastsquares adjustments for every "double-in-all-combinations" session separately. In 2001, standard deviations of section lengths varied between ± 0.08 and ± 0.20 mm, and standard deviation of a length measured from both ends between ± 0.14 and ± 0.19 mm. In 1997 these parameters were not much larger, but variations between sessions were clearer. The final results are the mean values of observations in several days. Different weather conditions are obviously the main reason for the slightly different scale between 1997 and 2001, and due to unfavourable weather conditions uncertainties of results in 1997 are larger than in 2001. Appropriate equipment and acknowledged methods can't ensure good results, if natural conditions are unsuitable. Final results and uncertainties are presented in Table 2.

Fig 5. Scheme of Kyviðkës Calibration Baseline (1 320 m) and Net

Interval	Lengths a	Difference and uncertainty, mm	
	1997	2001	
1 – 2	100 163.5 ±0.4	100 163.3 ±0.2	-0.2 ± 0.4
1 – 3	360 175.1 ±0.6	360 175.2 ±0.4	+0.1 ±0.7
1 - 4	1 120 379.2 ±1.0	1 120 378.5 ±0.6	-0.7 ± 1.2
1 – 5	$1\ 300\ 472.6\ \pm 1.2$	1 300 471.6 ±0.7	-1.0 ± 1.4
1 – 6	$1\ 320\ 482.6\ \pm 1.2$	1 320 481.6 ±0.7	-1.0 ± 1.4
2-3	260 011.6 ±0.6	$260\ 012.0\ \pm 0.3$	$+0.4 \pm 0.7$
3 – 4	760 204.1 ±0.8	760 203.3 ±0.5	-0.8 ± 0.9
4 – 5	180 093.4 ±0.4	180 093.1 ±0.3	-0.3 ± 0.5
5 - 6	$20\ 010.0\ \pm 0.4$	20 010.0 ±0.3	0.0 ± 0.5
1 – 7	_	841 806.5 ±0.7	_
2 - 7	_	775 236.9 ±0.7	_
3 – 7	_	644 376.3 ±0.7	_
4 – 7	-	804 745.9 ±0.7	-
5 – 7	-	933 818.8 ±0.7	-
6 – 7	_	949 186.1 ±0.7	_

Table 2. Baseline section lengths (mm). All differences are within the extended (95%) uncertainty limits.

In addition to lengths, angles in the triangle 1-6-7 were measured on October 25, 2001, with the theodolite Wild T2002 Theomat. All the seven pillars have been observed by GPS receivers as well. The results of short GPS sessions for the pillars are close to the lengths obtained from calibration by the EDM instruments, but shouldn't yet be compared due to different accuracy level. Nevertheless every pillar has coordinates in the Lithuanian Coordinate System LKS 94.

The baseline and the network in Kyviðkës are a remarkable national and even international resource in geodetic metrology. Procedures followed in the work meet the requirements of the quality standards ISO 17025 and ISO 9001. In September 2001 National Accreditation Bureau of Lithuania presented an accreditation certificate to the laboratory in the area of EDM calibration.

6. F. G. W. Struve's Geodetic Arc points in Lithuania

The International Institution for the History of Surveying & Measurement of the International Federation of Surveyors (FIG) has a goal to perpetuate F. G. W. Struve's Geodetic Arc as UNESCO World Heritage Sites from 1994 (annex 1). Such resolution was accepted in Melbourne 1994 FIG congress. This initiative was supported by International Astronomical Union (IAU), International Association of Geodesy (IAG) and CERCO.

Lithuanian National Land Board at the Ministry of Agriculture and Institute of Geodesy of Vilnius Gediminas Technical University have suggested to perpetuate 2 Struve's geodetic arc points – Meškonys (Meschkanzi) and Gireišiai (Karischki), the points of National Geodetic Network (Fig 7, 8). Suggestion was supported by Commission for National Heritage of Lithuania and Department of Cultural Heritage of Lithuanian Ministry of Culture.

By creating non connected triangulation networks C.Tenner and F.G.W. Struve thought to use accumulated data for solution of main geodetic task: determination of meridian length and computation of ellipsoid, best fitting Earth shape and size parameters. To achieve these goals the decision of connection of C.Tenner's and F.G.W. Struve's triangulation networks was achieved. The decision was implemented in 1829, by measuring triangulation chain between Pandëlys in Lithuania and Bristen in Latvia. Field observations mainly were carried out by Vilnius University graduate J. Chodzka (1800 – 1881).

First order triangulation network of the Vilnius province designed by C.Tenner, consisting of 119 triangles, was connecting 98 points. Average length of triangle sides was 25 km. Angles and baselines were measured in 1816–1821, later in 1822 – 1829 network was extended to Kurland province – Latvian territory nowadays.

Reference point for establishment of Vilnius province triangulation network was point on the top of the hill close to Meškonys village, 28 km North from Vilnius Astronomic Observatory. Temporary astronomic observatory was established at this hill in 1818. The latitude of this observatory was determined by C.Tenner from multiple observations of zenith distance of stars close to North Pole. The result was N=54/55'56,5''.

For determination of astronomic longitude difference of Meškonys and Vilnius observatories, synchronised time signals were transferred by light of burning gunpowder on the hill visible from both points. Astronomic observations were performed by professors of the Vilnius University. Jan Sniadecky (1756–1830) and Peter Slavinsky (1795–1881) at Vilnius Observatory and C.Tener with assistants at Meškonys point. The difference of longitudes was computed from triangles after completing triangulation network. The

discrepancy of longitudes was negligible, therefore final result was taken from astronomic longitude determination. Astronomic latitude of Meškonys point from Paris was 8=22/58'02,55''.



Fig 7. GPS receiver at the site Meškonys (Meschkanzi)

It must be stated that Meðkonys point coordinates have not been used for the computations of triangulation network. For this purpose temporary astronomic station was established at Nemëžis point in 1826, in 6 km East-Southwards from Vilnius observatory, where astronomic coordinates were determined from observations. For triangulation network computations only determined latitude was used. The latitude was computed from longitude difference of -1/24'13,50" [4] between Nemëþis and Tartu observatories, using triangulation of 1828. Azimuth of triangle side Nemëþis – Meðkonys was determined in 1839, by observing stars close to Pole by passage instrument. Triangulation points coordinates were computed from Nemëþis point: North longitude N=54/39'03,23"; East latitude 8=22/58'02,55". Azimuth of direction Nem žis – Meškonys " =359/59'57,93". Based on these initial data the coordinates of Vilnius province triangulation points included into Geodetic Arc chain were computed.



Fig 8. Photography of the site Gireišiai (Karischki)

Lithuanian National GPS Network was established after the gaining independence and has replaced the national triangulation used for 170 years. The network was based on GPS points observed during international program EUREF BAL92. Zero Order GPS network was established in Lithuania, Latvia and Estonia and connection to European Network EUREF 89 was established. Lithuanian Zero Order GPS Network was composed of 4 points (including Meškonys). First Order GPS Network, composed of 48 points evenly spread within the country, was designed and observed by specialists of Institute of Geodesy, Vilnius Technical

University in 1992-3. Based on Zero and First Order National GPS Networks of Lithuania a new Lithuanian Geodetic Coordinate System LKS 94 was introduced in 1994.

Lithuanian National GPS network was densified in 1994 – 1996. By this Second Order network of 1026 points was established. Some modern and pre-war geodetic reference points coincide with XIX century triangulation chain points for geodetic arc determination. New points positions corresponding to triangulation chain points of V.Struve's geodetic arc computations are presented in Table 3.

Table 3. Co-ordinates of modern geodetic points, corresponding triangulation points established for Struve's Geodetic Arc computations and declared as cultural heritage

Tria	ngulation of 1816-	1829	National GPS Network of 1992-1996			
Name of the point	Transformed coordinates to LKS 94		Name and code of the point	Coordinates of LKS 94		
	Latitude	Longitude		Latitude	Longitude	Ellipsoidal height, m
Meschkanzi	54/55'51,44"	25/19'00,36"	MEŠKONYS 73S–0312	54/55'51,38821 "	25/19'00,31622	229,515
Karischki	55/54'08,60"	25/26'12,54"	GIREIŠIAI 75S–0045	55/54'08,67973 "	25/26'12,41877	147912

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