The New Role of Geodetic Networks in Hungary

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Key words: classical networks, GNSS passive and active network, integrated network, reference system

SUMMARY

All geodetic positioning is carried out in a given reference system which is based on the geodetic control point network. The role of geodetic networks is changing due to the growing influence of satellite positioning. The use of active networks and the so-called integrated networks is increasing, thus greater emphasis should be placed on maintenance of these networks. Until there are such maps that rely on traditional horizontal and vertical networks, the key (a smaller number, though) points of traditional networks ought to be kept too. The paper presents the brief history and characteristics of the Hungarian traditional horizontal, vertical and GPS networks. It justifies the need to re-measure the vertical network. It includes the plan of developing the integrated network. It draws attention to the importance of preserving and maintaining points.

SUMMARY (Hungarian)

Minden geodéziai helymeghatározás egy adott vonatkoztatási rendszerben történik, amelynek alapja a geodéziai alapponthálózat. A műholdas helymeghatározás szerepének növekedése révén a geodéziai hálózatok szerepe változik. Növekszik az aktív hálózat és az ún. integrált hálózat használata, jelentősége, ezért ezek karbantartására, fenntartására kell nagyobb hangsúlyt helyezni. Mindaddig, amíg lesznek olyan térképeink, amelyek alapja a klasszikus vízszintes és magassági hálózat, a klasszikus hálózatok fontos (de jóval kisebb számú) pontjainak fenntartásáról is gondoskodni kell. A cikk bemutatja a magyar vízszintes, magassági és GPS hálózat rövid történetét, jellemzőit. Indokolja a magassági hálózat újramérésének szükségességét. Bemutatja az integrált hálózat kiépítésének tervét. Felhívja a figyelmet a pontvédelem és karbantartás fontosságára.

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1. INTRODUCTION

On the one hand, the establishment, type, and role of geodetic networks are determined by the historical-social circumstances, on the other hand, by the technological-technical development. This change will be illustrated using Hungarian networks as an example.
Hungary, located in the heart of Europe, had been the road of armies; the country's history was shaped by the influence of the East and West. Following one and a half centuries of Turkish rule (1526-1688), the country became part of the Habsburg Empire till the end of the First World War (1918). In the interwar years (1918-1945), the form of government was kingdom without a reigning king; after the Second World War it was people's republic within the Soviet Bloc, interrupted only for a few weeks by the Hungarian Revolution of 1956. As a result of political-social changes which started in 1989, Hungary has been a member of the European Union since 2004.

The troubled history (experienced by many other countries, such as Vietnam, too) is one of the reasons why the traditional geodetic networks in Hungary had to be rebuilt several times. By the time the traditional horizontal and vertical networks had been created following a work of numerous decades, the GPS-technology – which requires not only the previously adopted approach resulting from one measurement known as passive network, but also the constantly operating active network of permanent stations – was introduced. Hungary followed the global trends and consequently created the above-mentioned spatial networks.

It seems that with the development of the traditional and GNSS networks we no longer need to deal with this issue, but as a matter of fact, new questions arise: the need for re-measurement, the establishment of integrated points, the determination of the number of points to be preserved and maintained. And one more question: the necessity for networks must be justified. Apparently, geodetic networks have no direct benefits, but their maintenance costs money which is provided generally from the central budget. Therefore, it is important that the decision makers be informed, so that it will be clear for everyone that without networks we cannot talk about reference system, without control points we would be unable to perform our positioning tasks.

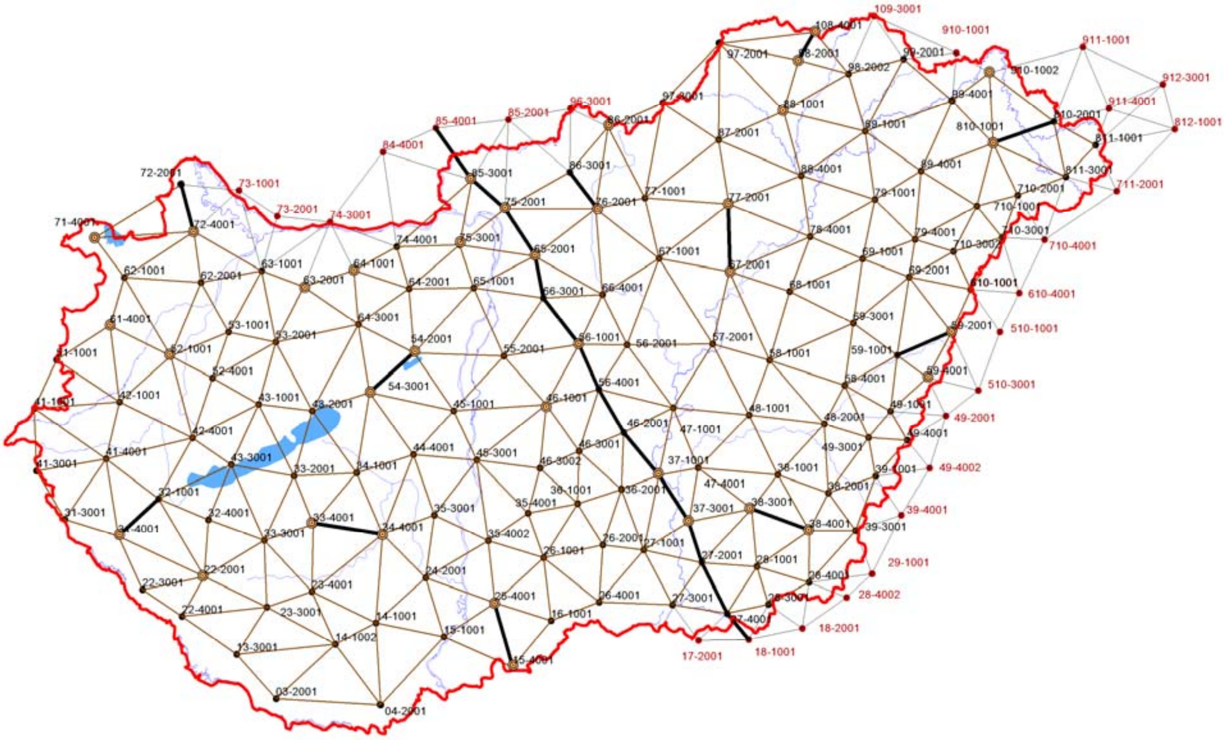
Networks form part of the spatial data infrastructure. The worldwide networks of GNSS infrastructure are partly maintained by the operators of GNSS basic systems (GPS is run by the American Air Force and the military mapping service) and partly by civil international organizations (IGS, IERS). Europe possesses such a network or service in continent size as well (EUREF, EPN). It is in the best interests of all countries to create the national spatial data infrastructure, including the maintenance of geodetic networks. Let us take the Hungarian networks as an example.

2. CLASSICAL GEODETIC NETWORKS

2.1 Unified National Horizontal Network (NHN)

The horizontal network extending over the whole country was first established between 1860 and 1913, then because of the First World War a new one started to be built (1925-1944). The establishment of the horizontal control network used even today became necessary due to the destruction caused by the Second World War, but the entire process took more than four decades (1948-1992).

In the first phase between 1948 and 1952, a chain of first-order triangles (with 30 km sides on average) running along the border was made, which was connected by a brace chain in the middle. In order to speed up the works, the filling network was created with 7 km third-order triangles instead of using 30 km first-order triangles, which means that the hierarchy lacks second-order points. Good weather conditions occurring sooner and more frequently therefore made it possible to observe shorter directions, and the cost of pyramid construction also dropped.



The Hungarian first order horizontal network

The second phase of establishing this network included: network improvement, additional measurements and final calculation. Electronic distance meters appeared in the 1960s, which provided the chance to measure the length of several first-order sides directly. The final calculation and free adjustment of the network took place in 1972, that's why the geodetic datum derives from here (Hungarian Datum, HD72). The importing data of adjustment: altogether 900 directions, 23 ellipsoidal distances and 40 azimuths. The RMS of direction

measurement after the adjustment was *m=0,434"*. In the case of an average 30 km side, it means a linear bias of 63 mm which is equivalent to an average relative error of *R=1/475 000, (2,1 ppm)*. The first-order network has altogether 167 points, 141 from which can be found in Hungary, while the rest ensure the relationship with the neighbouring countries.
As Hungary was a member state of the Warsaw Pact, the base-surface of the network was originally designed to be a Krassovski ellipsoid and a Gauss-Krüger projection was chosen as its projection system. The very same network was actually used for two purposes, namely the formation of a military and a civil reference system. The base surface of the civil reference system was a GRS67 ellipsoid, and the grid coordinates were obtained on a reduced cylindrical projection thanks to double projection (EOV). The calculation of third-order points and that of low-order points later on took place in the projection plane.

Practical surveying purposes required points that were located more densely, 1-1.5 km far from each other on average, which was fulfilled by the fourth-order horizontal point position fixing. In the beginning (i.e. in the 1960s), 9 thousand points were determined by traditional triangulation based on simple direction measurement. The direction- and distance measurement technologies dominated the 1970s-80s, some 34 thousand points were determined by long-side traversing and trilateration. The land surveyings triggered by the privatization urged point position fixing, which was possible only with the GPS technology (4 thousand points). So, altogether 47 thousand fourth-order horizontal points had been placed by the middle of the 1990s, which represent the traditional horizontal network in Hungary.

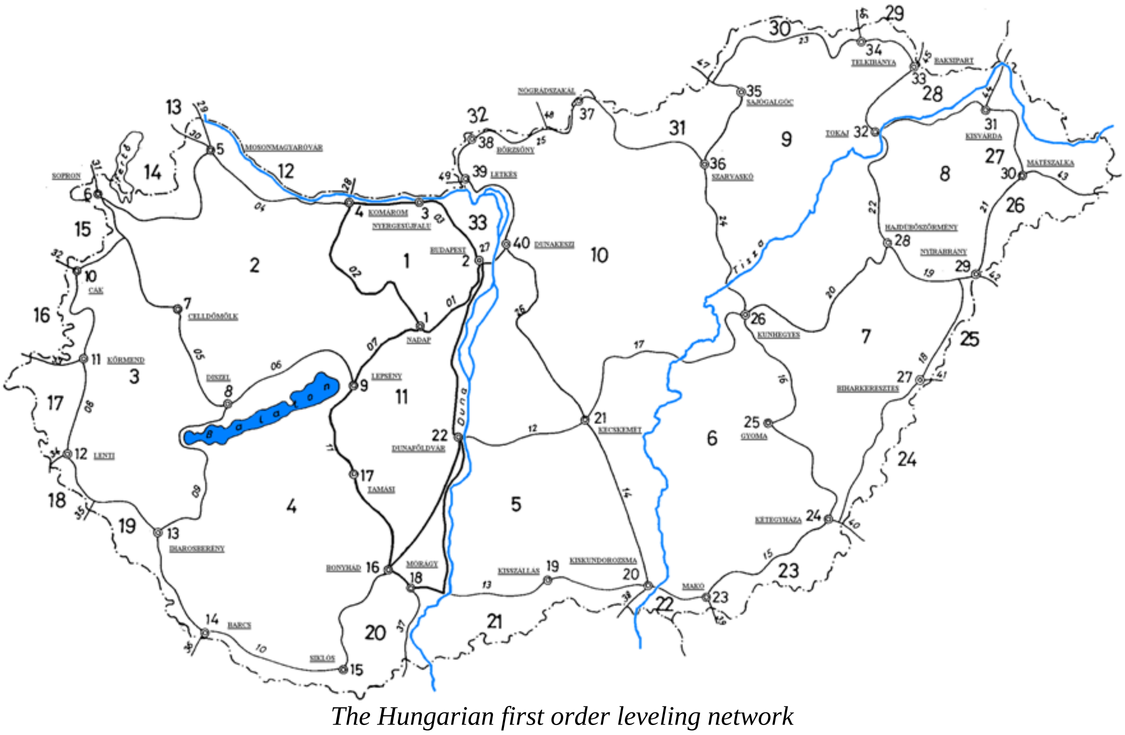
Measuring tower and protectived stone on the outside field

Benchmarks are distinguished depending on where they are used: in general, stones are used outside, while copper bolts on covered surface. Two special markers are worthy of note. At the first-order points the traditional temporary pyramids have been replaced with 8-30 m high, cylinder-shaped measuring towers made of reinforced concrete. More than 100 such towers have been built in the country. Stones situated outside in the fields have been equipped with pyramidal frustum-shaped protective cover made of reinforced concrete sheets in order to avoid serious damage.

2.2 Unified National Vertical Network (NVN)

The first leveling network extending over the whole country was established in the time of the Austro-Hungarian Monarchy (1873-1913); the measurements were taken by army officers. The main benchmark found at Nadap in the Velence Mountains, which is the starting point at a given height of all our networks, originates from this period. Because of ”the storms in history”, specifically the two world wars, two additional leveling networks had to be created (1921-1944, 1948-1964). The base level of the vertical networks was initially the mean see level of the Adriatic Sea, from the 1960s that of the Baltic Sea.

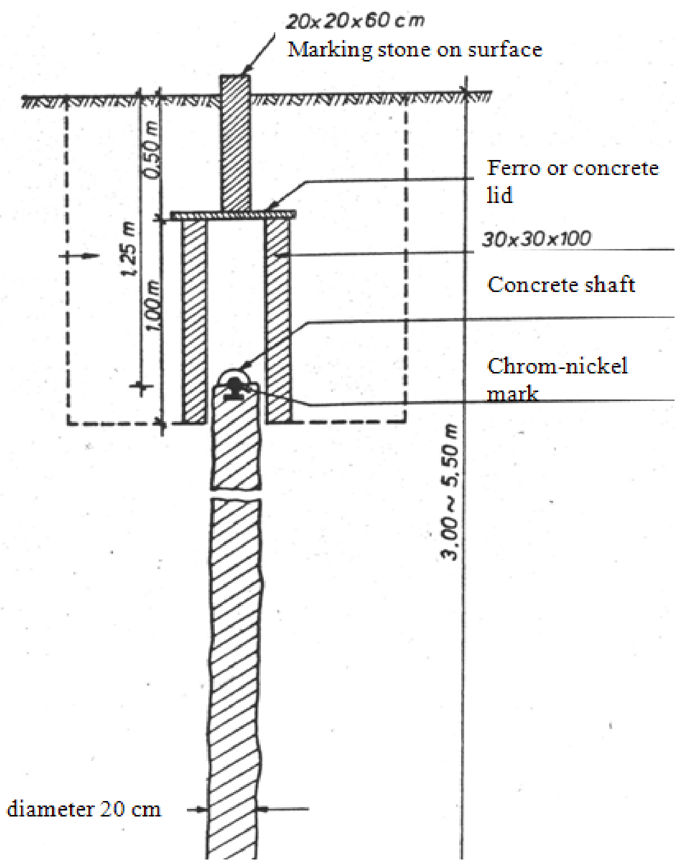
In the 1960s, the idea of monitoring the changes of the earth’s surface and crust from repeated levelings began to germinate. This needed new types of benchmarks and new measurement. The vertical network (NVN for short, EOMA in Hungarian) used even today started to be built. The national network consists of first-, second- and third-order levelling lines and points, the average point density is 1 point/4km^2. Some 25 thousand leveling control points can be found in the country.



The Hungarian first order leveling network

The first-order network was completed in the 1970s, then the first-order polygons were densified with second- and third-order points. This point densification took much more time than previously thought, due to financial difficulties (other important state programmes). Thus, the formation of the entire NVN lasted for nearly four decades (1968-2006).

The measuring method of the first- and second order networks was precise leveling with the aid of the NiA31 compensator level developed by the Hungarian MOM factory. The usual instrument-leveling rod distance was 25-30 m; in the beginning the record was compiled manually, (from the 1980s) the readings were put down into a pocket calculator. Since 2005, there has been a switch to digital leveling instruments (Leica NA3000, DNA03).



Profile of crustal movement point

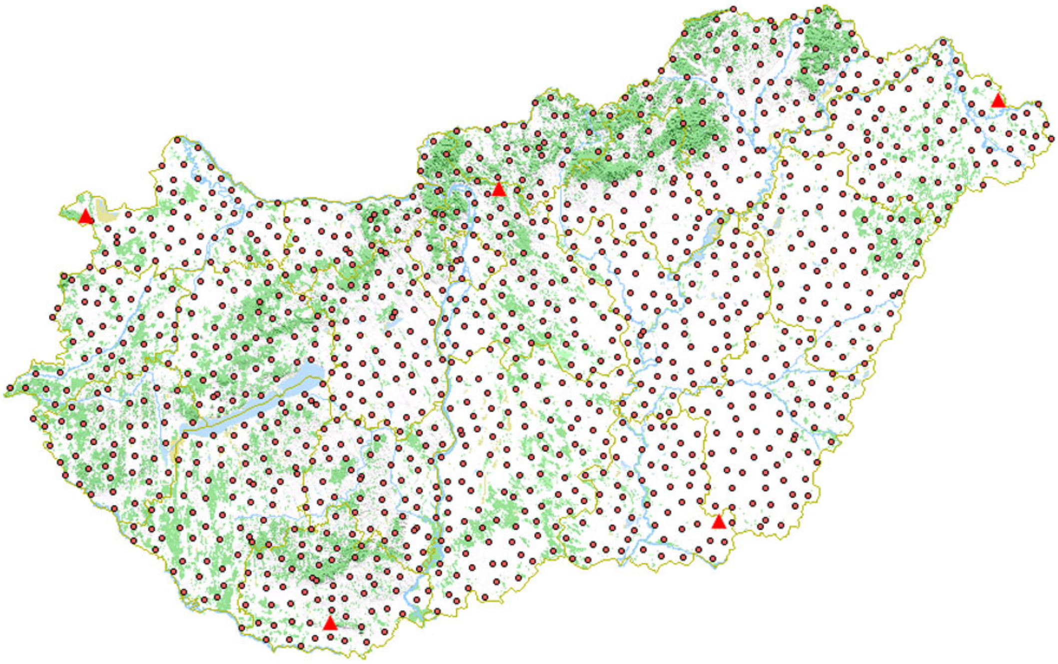
Since 1998, the third-order leveling has been replaced with the so-called GPS vertical measuring technology. This was first tested in a second-order polygon and introduced on the basis of positive experiences. Its essence is the fitting that results from a precisely measured GPS network and a GPS gravimetric geoid. The points of the precise GPS network include not only the new third-order ones, but also such second-order points which possess freshly leveled height. The duration of the static measurement at these second- and third order points is 6 hours. The classic aspects of leveling do not count towards selecting the third-order points, i.e. the points are not found in a line but in a proper spatial distribution. As the GPS measurement provides WGS84 ellipsoidal height, a geoid model covering the working area (the second-order leveling polygon) is crucial for the height above sea level. The geoid model was installed locally according to the second-order leveling points functioning as junction points where the difference between ellipsoidal height and leveled height was known. After that it was possible to transform the ellipsoidal height of the third-order points into Baltic height. Results show that the RMS of the height is 5 mm.

The benchmarks of vertical control points are typically leveling rivets in buildings and stones outside. A special way of marking of the NVN is the concrete pile placed at a depth of 3-5 meters and locked 1 meter below ground by a shaft inside which there is the levelling knob. The benchmark what we call the crustal movement point (CMP) derives from the aforementioned points which make it possible to monitor crustal movements. In the first-order network CMPs are found at a distance of 5 km, while in the second-order network at a distance of 20 km on average.

3. GPS-GNSS NETWORKS

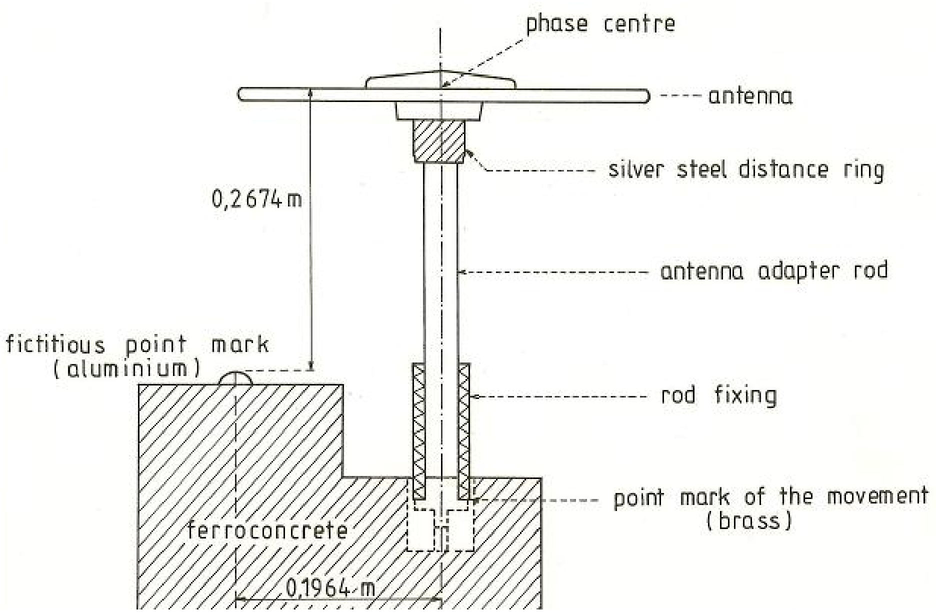
3.1 National GPS Network (NGN)

In the early 1990s, there was a debate in Hungary whether the GPS network is essential, and if so, how dense it should be and which technology meets the needs best. For a short story only the end result gets a mention here: between 1991-1997, a passive GPS network comprising 1153 points was built. The average point-point distance is 10 km (1 pont/80km^2). The points of the NGN are not new, but identical to the ones of the NHN, and of course, the way that they were selected from the horizontal points provides easy access from roads as well as open sky. One of the aims of the NGN is to fulfil the spatial reference system so that a sufficient number of reference points will be available for GPS measurements in terms of density. The possibility of fitting the results of GPS measurements into the reference system of the maps in use (HD72) is also of great importance. In this respect, the NHN-NGN points tend to be good indeed. It is interesting to note that the Hungarian State Geodetic Survey offers such a software (EHT) for free that is capable of solving the WGS84-HD72 transformation, producing the best local fitting (with RMS of 2-5 cm for fitting). The database of the software is made up of the total number of NGN points as common transformational point. The program selects all the junction points within 15 km (usually 5-8 points) independently for each point to be transformed, calculates the 7 parameters of the spatial similarity transformation, then transforms the point. The measurement technology of the NGN was a fast static survey, 9 receivers were measuring during one session, then 3 receivers continued to serve as junction points for the next session. The duration of the measurement was 20 minutes, and 40 minutes following the new setting up. The obligatory, repeated setting up of the instrument was intended for avoiding the error of the antenna height, while the longer duration made the processing of vectors safer.



The points of Hungarian passive national GPS network

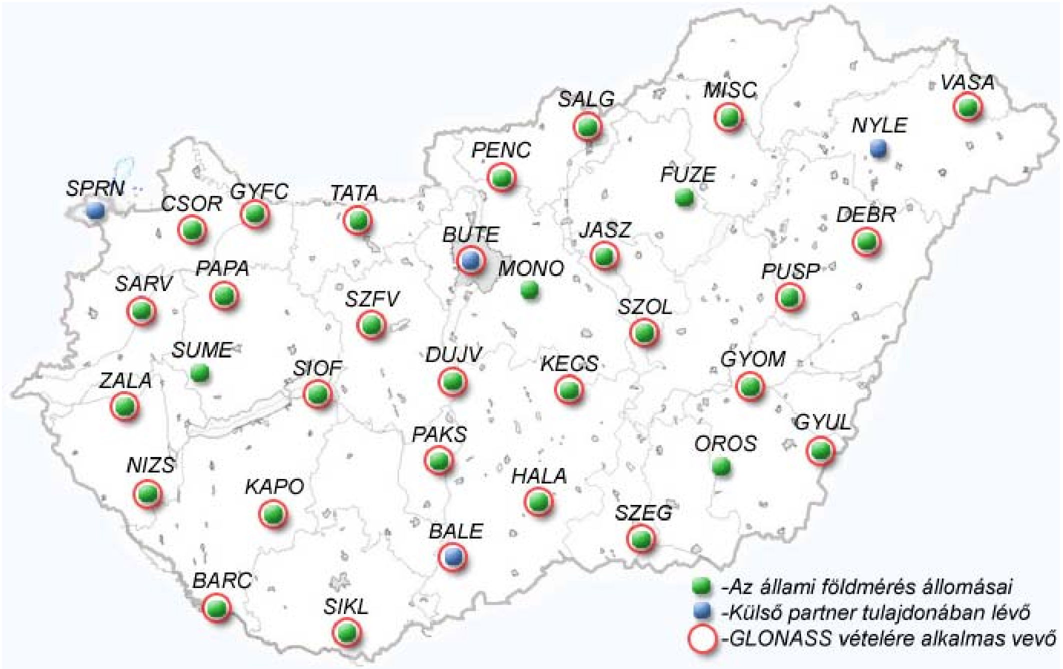
The reference system of the NGN is the ETRS89. Its introduction in Hungary took place as part of a one-week Eastern-European measurement campaign in 1991 with German assistance, involving 5 Hungarian points. On the basis of the aforementioned five points, first, a so-called frame network composed of 24 points was installed. These 24 points served as given points when the NGN was being adjusted. Another aim of the NGN frame of reference is the geodynamic monitoring which is operating at national and regional (Central-European) level. Since 1991, the geodynamic GPS campaigns have been organized every two years within a session of 3×24 hours. Now we should have a look at the marking of the geodynamic points established at the control stone. This is a so-called stepwise point. The aluminium knob found on its surface is used for ordinary measurements. The real benchmark, into which a copper adapter rod of well-defined length can be screwed so that the proper setting up will be ensured, is 10 cm below ground.



Stepwise GNSS pointmarker for geodinamical use

3.2 The Hungarian Active GNSS Network (GNSSnet.hu)

Nowadays, the active networks tend to contribute to the maintenance of spatial reference systems not only globally, but also at national level. The first permanent station was established in the Satellite Geodetic Observatory at Penc in 1996, however, a lot of time had passed until the entire active network was completed. The fairly slow installation can be explained with the shortage of resources and the lack of financial means, but the criteria for the real-time services also developed step-by-step and took long time.



The points of Hungarian active network (www.GNSSnet.hu) in July 2009

The reliable internet connection with the head office, the standardization of the internet protocol and data format, and the real-time mobile phone connection still had to be solved. The Hungarian active network was eventually completed in 2008. The original plan was to build 12 stations, but this number finally rose to 35. The network-based performs satisfactorily only if the stations of the neighbouring countries also belong to it, thus there is a mutual exchange of data between the neighbouring countries under the terms of contracts. Most of the permanent stations have become 2G types (GPS+Glonass). The software of the German Geo++ Co. controls the data processing and service in the head office (centre).
Services are divided into two types: for postprocessing and for real-time. The data of any station can be downloaded for any date at any intervals via a GNWEB server, and it is possible to receive fictive measurement data generated for any position too (virtual RINEX). The generation of the latter data is provided by the state space representation model according to the state vectors stored per second. Real-time data may come from permanent stations for code measurement only (DGPS) or phase measurement (single-base RTK) as well. The real-time data service is getting more and more associated with Network RTK whose users represent the highest number. All three conceptions of Network RTK that have been accomplished up to now (VRS, FKP, MAC) are available not only via the generation of GPS data, but also Glonass data.

4. THE PLAN OF INTEGRATED NETWORK

Geodetic control points whose positioning data have been determined in various reference systems, which certainly means the use of various measurement techniques, are called integrated points. The NGN points in Hungary are considered to be elementary points, because they are horizontal and GPS points at the same time. They would be real integrated points if they possessed Baltic height deriving from the original measurement. This precise leveling, or rather its cost, is problematic, though. Measuring the first and second-order vertical control points with the aid of precise GNSS seems to be the most workable solution. The practical solution was motivated by two real user demands.

One of the user demands is in connection with a more wide-ranging use of the GNSS technique. More and more people wish to determine the height above sea level with higher accuracy, using Network RTK for instance. Unfortunately, the vertical transformation cannot be carried out accurately enough in the absence of GPS-NVN common points and precise geoid. The other user demand relates to precise vertical data on a larger working area. By way of illustration, vertical control points in an area of at least 10-100 km should be provided for motorways. The reason why this is not yet possible today is that the control points have vertically moved in the past decades, i.e. the network is not homogenous. (Now we are not thinking about deep mining or the explotation of oil and water which lead to quite significant surface movements but smaller and natural ones.)

Consequently, the plan of the Hungarian integrated network was designed as follows. It was agreed that the NVN should be re-measured; not the whole network, just the first-order part. This work must be finished as soon as possible, although it will take a few years owing to financial opportunities. Only digital leveling instruments of the same type can be employed, and simultaneously gravimetric measurements have to be taken. At those existing leveling points that are suitable for GPS measurements (clearly visible leveling stones), GPS measurements should be organized. If there are no such points along the first-order line, then some should be established. The so-called integrated points will be placed at the vertical control points found every 20 km on the line where GPS measurement is possible. The leveling and the GPS measurement must be carried out close together in time, in the same season at least. The duration of the static GPS measurement is 12 hours. The end result of the project will be not only a brand-new leveling network, but also a spatial (GNSS) network and a geoid model that is appropriate to practical purposes. The work has already started in Hungary, however, it is difficult to estimate when it will be accomplished due to the economic crisis.

Our opinion is that integrated network serve real demand, this is the only way for more precise and wider use GNSS technology. The integrated points will be the basis for whatever measuring technique (angle- and distance measurement, leveling, GNSS).

5. THE MAINTANCE OF GEODETIC NETWORKS IN THE FUTURE

The question is: do we need to re-measure the national networks presented in the previous chapters, and preserve and maintain the control points in the new situation? The decision makers (operators) are certainly not indifferent to this issue, since they pay considerable sums for building and maintaining the networks.

Our professional answer briefly sounds like this: it is necessary to re-measure the active and levelling networks, but the GPS and horizontal networks are fine. The re-measurement is the

„natural condition" of the active network, because the coordinates of points are at our disposal in the so-called daily and weekly solutions again and again. The employees of the head office are therefore required to work hard and make a contribution (analyzing the coordinate time series, excluding the movement of points, creating new coordinates, maintaining the continuous operation and data connection, following the development of reference systems). In justification of the need for the re-measurement of vertical networks, we claimed that the points had vertically moved and there was a demand for a more accurate geoid model. The precise levelling technology supplemented with gravimetry still produces the most accurate result nowadays, so the re-measurement of the first-order network with the aid of leveling is essential at certain intervals.

Both the (passive) NGN and the NHN used to provide an adequate point density at that time, its accuracy was appropriate for the earlier technology. None of the networks needs to be re-measured since we would be unable to produce a more accurate end-result, but the costs would definitely be huge. In view of the fact that we employ the GNSS technology more and more in order to determine horizontal points (points to be represented on traditional maps), we should study the relationship between the two networks in greater detail, not only at national level, but also the local contradictions – we have work to do in this field in Hungary.

In the new situation the role of traditional networks is re-valued as a result of the progress of satellite positioning. In fact, there is no need for horizontal control points in such density as it was designed according to a former technology. Reference systems are getting increasingly dependent on active and integrated networks, thus the running costs should be directed here. The number of traditional geodetic control points to be preserved by all means can also be reduced. The annual reconnaissance and substitution of points in Hungary would extend over the following control points: points of the integrated network, points of the NGN, first and second-order points of the NVN, and high-order (first and third) points of the NHN. The number of control points to be preserved in the future (involved in the reconnaissance) would only be 20% of what we currently have, which results chiefly from the decrease in the number of horizontal control points. This means that if a control point not to be maintained was destroyed, the cost of substitution should be appropriated for the preservation of those points which are considered more important. We are faced with a lot of questions and joint thinking regarding this subject such as determining the group of integrated points, designating the points of reconnaissance, prescribing the substitution technology, solving the means and resources of reconnaissance and maintenance, creating the digital system of the new professional regulation and registry.

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BIOGRAPHICAL NOTES

György BUSICS was born in 1953 in Szombathely, Hungary. He attended the Land Surveying Branch of the Budapest Technical University. From 1977 he was working as a land surveyor at the local offices of the State Enterprise of Cartography for four years, where he took part in large-scale mapping. He started to work at the College of Geoinformatics in Székesfehérvár in 1981 and he has been teaching and researching here since then. At present he is head of surveying department and responsible for the following subjects: Geodetic Networks, Satellite Positioning, Quality Management. He takes an active part in the Hungarian application of the GNSS technique; his publications are mostly dealing with it. He is a member of Geodetic Committee under Hungarian Academy of Sciences and fellow of Hungarian Society of Surveying, Mapping and Remote Sensing.

Mihály ÁGFALVI was born in 1941 in Szatmárnémeti. He graduated as a land surveyor engineer at the Technical University of Budapest in 1967. He worked at the Company of Surveying in Budapest from 1967 until 1970. In 1970 he was appointed as an assistant at the Department of Geodesy of the College of Surveying and Land management in Székesfehérvár. He obtained his Dr. techn. academic title at the Technical University of Budapest in 1979. Currently he works as a Professor at the Department of Geodesy at the Faculty of Geoinformatics, University of West Hungary. He actively took part in the work of Hungarian National Committee (HNC) of FIG and was the president of HNC from 1998 to 2002. He is also the member of the executive committee of Hungarian Society of Surveying, Mapping and Remote Sensing, and the vice-general secretary of Society. His teaching and research work are focused on Engineering Geodesy.

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