INTRODUCTION AND IMPLEMENTATION OF ESRS IN CROATIA

UVAJANJE IN IMPLEMENTACIJA ESRS NA HRVAŠKEM

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UDK:528.236(497.5)

ABSTRACT

The purpose of the paper is to present the entire procedure which was done by the State Geodetic Administration and the Faculty of Geodesy University of Zagreb in last decade, in order to introduce and implement the new modern geodetic reference system in the Republic of Croatia. Beside the new positional datum, based on European Spatial Reference System, the introduction of new vertical and gravimetric datums, as well as new cartographic projections are described too. Problems connected with the transformation between the old and the new datums, as well as the implementation of the new reference system are also being considered.

KLJUČNE BESEDE

new geodetic datum, Croatia, introduction, implementation

Klasifikacija prispevka po COBISS-u: 1.02

IZVLEČEK

Namen članka je predstaviti celotni proces uvajanja in implementacije novega sodobnega geodetskega referenčnega sistema v Republiki Hrvaški, ki sta ga v zadnjem desetletju izvajali državna geodetska uprava in Fakulteta za geodezijo Univerze v Zagrebu. Poleg novega geodetskega datuma, ki temelji na evropskem prostorskem referenčnem sistemu, je opisano tudi uvajanje novega vertikalnega in gravimetričnega datuma in novih kartografskih projekcij. Obravnavane so tudi težave, povezane s transformacijo med starim in novim datumom in z implementacijo novega referenčnega sistema.

KEY WORDS

nov geodetski datum, Hrvaška, uvajanje, implementacija

1 INTRODUCTION

In the paper »Proposal for the geodetic datum of the Republic of Croatia for the third Millennium« (Bašić and Bačić, 1999) the necessity of introducing a new geodetic reference system in Croatia was discussed for the first time. In a synoptic way there is a historical overview of the inherited datums (positional, vertical and gravimetric) given, including the review of fundamental geodetic works realized with the use of modern technologies since the beginning of 1990s, and the discussion of the transformation problem between the old (local) and the new (global) datum. This paper considers some basic principles, which should be fulfilled in such situations, with the compromise between the international and national requirements being particularly emphasized among them, and the possible future steps announced.

1.1 Historical datums

The inherited geodetic datums are connected to the states that Croatia used to be only a part of in the past (ibid.):

- Position datum: genuine Austro-Hungarian solution of 1901, slightly modified in ex-Yugoslavia (local datum, Bessel ellipsoid, Gauss-Krueger projection),
- Vertical datum: tide gauge in Trieste on pier Sartorio, epoch 1875 (registration only one year, normal orthometric heights),
- Gravimetric datum: MGI (Military-Geographic Institute in Belgrade) – activities between 1952 and 1974, Potsdam and partly IGSN71.

They are not well documented, and are of insufficient accuracy (possessing gross errors too), none or purely adoptive and usable to the new technologies and not able to respond to user demands. Therefore, the main reasons for introduction of new datums are: introducing unique Croatian official geodetic datums and map projections based on modern achievement of science and according to European recommendations and trends; removing the existing obstacles toward a more efficient use of modern measuring and GIS technologies and in that way offer the state, economy and the citizens a uniform, rational and simply applied reference system and frame; in the part that relates to spatial data to create prerequisites for development of information society in Croatia (e-government ...); to make further development of geodesy and other geo-professions possible.

1.2 Procedure of the new reference system introduction

According to the Croatian Law on State Survey and Real-Estate Cadastre (NN 128/99), the State geodetic administration of the Republic of Croatia (SGA) requested in 2000 three expert studies from the Faculty of Geodesy University of Zagreb:

- Prof. Dr. Tomislav Bašić – Study on horizontal and gravimetric datum (Bašić et al., 2000),
- Prof. Dr. Ladislav Feil – Study on height datum (Feil et al., 2000),
- Prof. Dr. Miljenko Lapaine – Study on map projections (Lapaine, 2000).

The delivered studies were reviewed in 2001 by Croatian and international experts. In (Brockman et al., 2001) the international experts from Norway, Switzerland and Germany concluded (quotation):

"We would like to emphasize that the Croatian colleagues have done a very good work in the preparations of this project. This includes the geodetic work in Croatia itself as well as the preparation of documents for the consultants, where basic information was given for the history, the current geodetic situation and ideas of the new system. These documents were the basis for many fruitful discussions we had in Croatia, and also for discussions between the consultants themselves. Detailed recommendations are given in the different chapters, taken into account that Croatia, as other European countries, has very limited resources available for geodesy. So our main conclusions are: Croatia is in a good position to achieve geodetic networks acceptable for European standards; the geodesists we have met in the project are well educated compared to

other European countries and they are well prepared for the tasks to be done; we recommend Croatia to change to the new geodetic reference system described in this report, and to start the preparations soon. Even if cost–benefit computations are not carried out, it is quite clear that Croatia in the long run will benefit on the change; priority should be given to finish the GPS densification network; it is important to measure gravity at levelling bench marks with a higher density than today; preparations for an even better geoid should be started (levelling connection to GPS points and measure with GPS in levelling bench marks)".

In 2003 SGA additionally requested the following three studies:

- Preparation of documentation necessary for the adoption of the official positional and gravimetric datums of the Republic of Croatia (Bašić et al., 2004),
- Preparation of documentation necessary for the adoption of the official height datum of the Republic of Croatia (Feil et al., 2004), and
- Preparation of documentation necessary for the adoption of the official cartographic projections of the Republic of Croatia (Lapaine et al., 2004).

On the basis of the prepared documentation by SGA and the Faculty of Geodesy, and Article 9 of the Law on State Survey and Real Estate Cadastre (NN 128/99), the Government of the Republic of Croatia adopted at its meeting on August 4, 2004 the Decree on establishing new official geodetic datums and map projections of the Republic of Croatia (NN 110/04). This Decree will be discussed in more detail in the next chapter.

2 NEW DATUMS AND THEIR REALIZATIONS

2.1 Horizontal datum

1) European Terrestrial Reference System 1989.0 (abbreviated as ETRS89), is defined to be the official inalterable and time independent positional reference coordinate system for the Republic of Croatia.
2) GRS80 ellipsoid with the size of large half-axis a=6378137.00 m and the flattening μ=1/298.257222101 is determined to be the official mathematical model for the Earth's body in the Republic of Croatia.
3) The positional network that consists of 78 permanently stabilized geodetic control points having the coordinates determined by ETRS89 is determined to be the basis of reference coordinate system of the Republic of Croatia (Fig. 1).
4) The positional reference coordinate system of the Republic of Croatia containing the coordinates of 78 geodetic control points determined in the year 1996, is given the name Croatian Terrestrial Reference System for the Epoch 1995.55 – abbreviated as HTRS96.

2.2 Vertical datum

1) Geoid surface, defined on the basis of the mean sea level at five tide gauges in Dubrovnik, Split, Bakar, Rovinj and Koper (Slovenia), is defined as the reference surface used for the computation of heights in the Republic of Croatia.

2) Vertical network consisting of permanently stabilized benchmarks of the II precise levelling, the heights (Fig. 2) of which are determined in the system of (normal) Earth's gravity field, is defined to be the basis of the vertical reference system of the Republic of Croatia.

3) Vertical reference system of the Republic of Croatia that is determined on the basis of the mean sea level is given the name – Croatian Vertical Reference System for the Epoch 1971.5 – abbreviated as HVRS71.

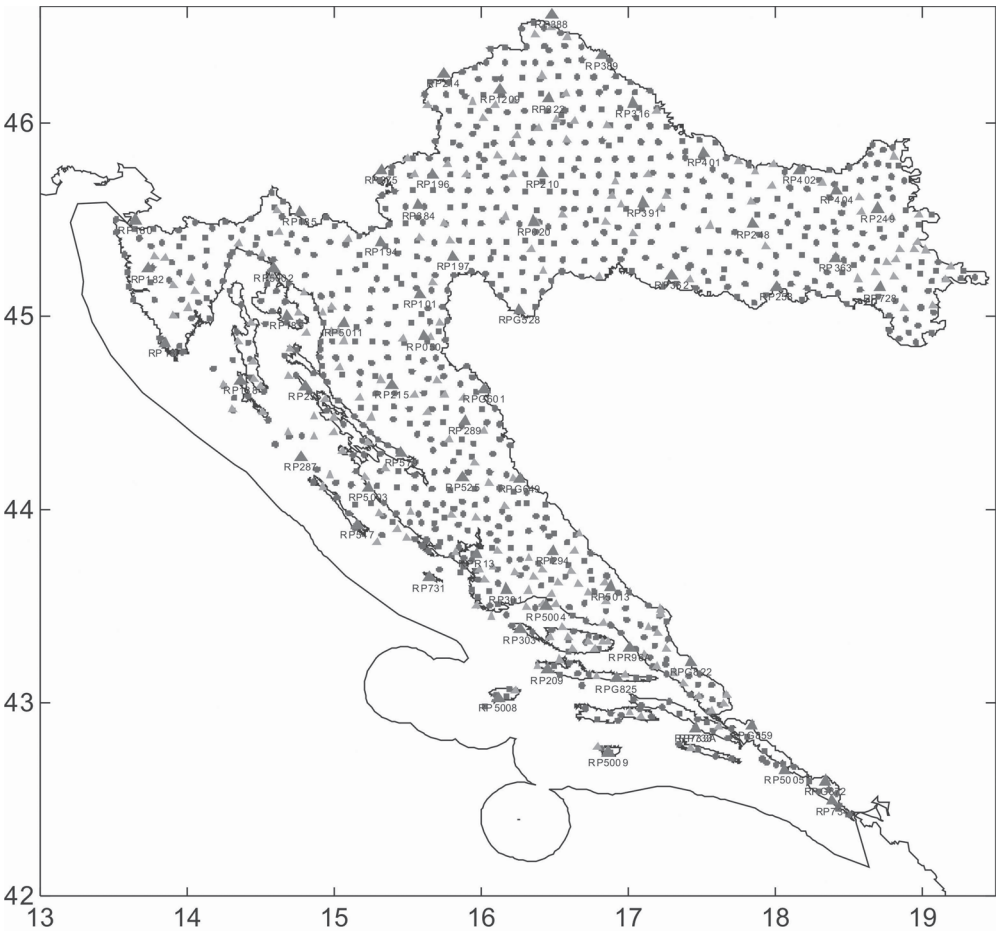

Fig. 1: *HTRS96 frame based on basic GPS network (78 points) and 10-km GPS network (1054 points).*

2.3 Gravimetric datum

1) The reference system for the determination of gravity, the basis of which is the *International Gravity Standardization Network 1971 (abbreviated as IGSN71)*, is determined by gravimetric reference system of the Republic of Croatia.

2) GRS80 ellipsoid with the belonging physical parameters GM=398600.5x10^9 m^3s^{-2} and with the angular velocity of the Earth rotation ω=7.292115x10^{-5} rad s^{-1} is defined as the reference

level-ellipsoid for the determination of normal gravity field in the Republic of Croatia.

3) The basic gravimetric network that consists of 6 permanently stabilized points of absolute gravimetric network and 36 permanently stabilized gravimetric points of the Ist order gravimetric network on which the gravity is determined in IGSN71 (Fig. 3), is being determined as the basis of the gravimetric reference system of the Republic of Croatia.

4) The gravimetric reference system, in which the gravity was determined at 42 points of the basic gravimetric network in 2003, is given the name Croatian Gravimetric Reference System 2003 – abbreviated as HGRS03.

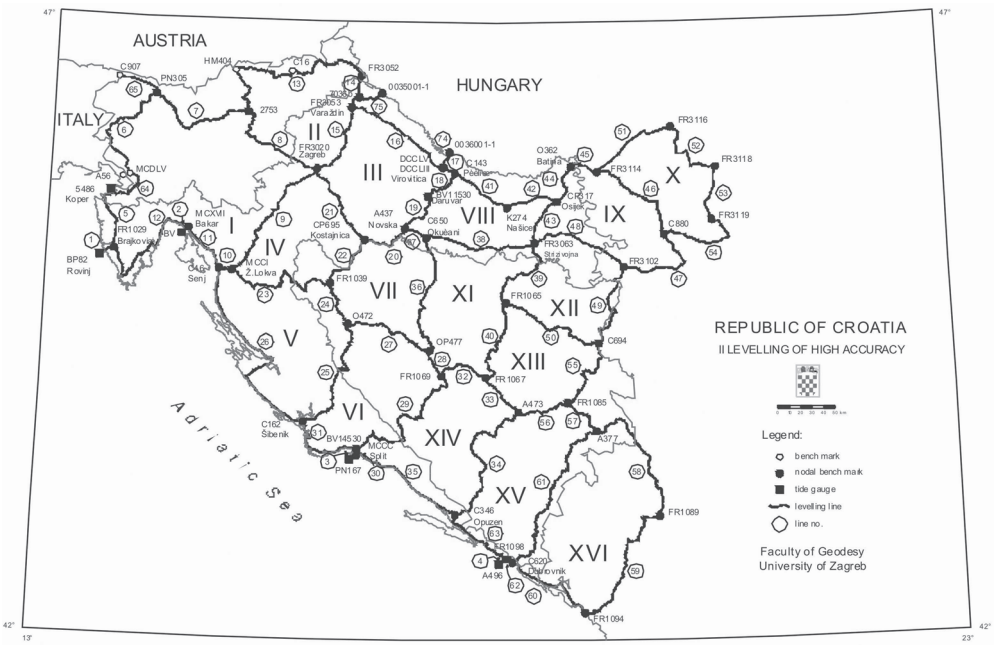

Fig. 2: *Five benchmarks and II precise levelling as the realization of the new vertical datum of the Republic of Croatia.*

2.4 Plane map projections

1) The coordinate system of the transverse aspect of Mercator's projection – abbreviated HTRS96/TM, with the mean meridian 16° 30' and the linear scale on that meridian 0.9999, is defined to be the projection coordinate system of the Republic of Croatia for the field of cadastre and detailed state topographical cartography.

2) The coordinate system of the normal aspect of Lambert conformal conical projection – abbreviated as HTRS96/LCC, with standard parallels 43° 05' and 45° 55', is defined to be the projection coordinate system of the Republic of Croatia for the field of general state cartography.

3) The coordinate systems of map projections are based on the Croatian terrestrial reference system defined in item I of this Decree.

4) To serve the needs of the Armed Forces of the Republic of Croatia, the projection coordinate system of Universal Transverse Mercator projection – UTM is adopted, pursuant to the Standardization Agreement "STANAG 2211", fifth edition, July 15, 1991, of the NATO member states.

The remaining articles in this Decree (NN 110/04) say that the new official geodetic datums and plane map projection will be implemented into the official use gradually. The director of the State Geodetic Administration is entrusted with the task of developing a program for implementing new official geodetic datums and map projections into the official use, within 6 months upon publishing this Decree. The State Geodetic Administration is entrusted with the task of implementing new official geodetic datums and map projections into official use until January 1, 2010 at the latest. The decision referring to method and dynamics of implementing map projection from item IV, section 4 above will be made by the Minister of Defense.

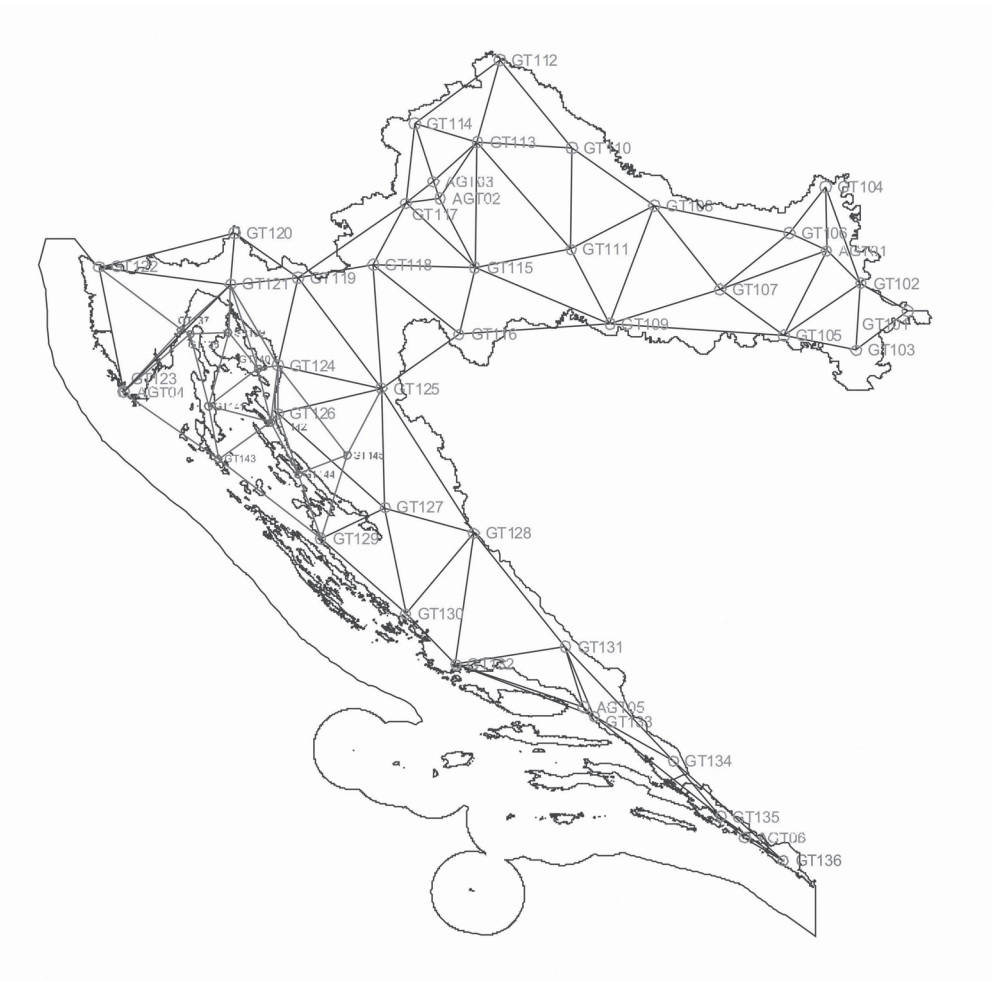

Fig. 3: *Fundamental gravity network as the realization of the new gravimetric datum of the Republic of Croatia.*

3 TRANSFORMATION

Resulting from an increasing number of GPS-technology users in Croatia, the Department for Geomatics at the Faculty of Geodesy, University of Zagreb has realized two special projects for the State Geodetic Administration yielding three separate computer programs: IHRG2000, DAT_ABMO (Bašić, 2004) and T7D (Bašić et al., 2006). The programs are written in Visual Basic 6.0 (Microsoft Group 2000) and they support all the latest Windows platforms.

3.1 IHRG and DAT_ABMO computer programs

In (Bašić, 2001) a new solution was presented for the geoid surface at the entire territory of the Republic of Croatia HRG2000. In order to provide its simple application, it is necessary to make a computer program for interpolation. These efforts resulted in the application IHRG2000 that enables quick and accurate determination of the geoid in any point at the Croatian territory. The program has been supplemented with the graphic maps of the Republic of Croatia that can be used for approximate input of point, and with the map of the Republic of Croatia having clearly marked geoid contours where all interesting points and the results can be seen.

The second computer program DAT_ABMO is designed for the transformation of coordinates between diverse geodetic datums and measuring epochs. Primarily it is provided to the GPS users, but not exclusively. With the program it is possible to calculate one's own transformation parameters, to transform the coordinates between different global datums and HDKS (old Croatian State Coordinate System) using the known transformation parameters at the state, county and city (local) levels, and to enable several conformal map projection calculations, like UTM and Gauss-Krueger projection.

The DAT_ABMO program is divided into the following tasks: spatial transformation of coordinates depending on time (Boucher-Altamimi formulas), spatial transformation of coordinates not depending on time (Helmert's 7-parameter spatial transformation), spatial transformation of coordinates depending on time caused by movements of the geological plate EURA (according to the parameters form the model NUVEL-1A), the computation of the parameters from Helmert's spatial transformation on the basis of identical points in both datums (adjustment of indirect measurements by using the least squares method), conversion of various coordinate record forms (Cartesian and ellipsoid – degree sexagesimal and decimal, as well as centesimal), cartographic projecting of ellipsoid or Cartesian coordinates into some of the offered cylindrical, conformal projections (transverse Mercator: GK-15E, GK-18E, GK-16.5E, as well as UTM-33N and UTM-34N).

3.2 New transformation model T7D

Within the frame of a special project for the SGA (Bašić et al., 2006) there has been a unique coordinate transformation model developed between a new positional Croatian terrestrial reference system HTRS96 (NN 110/2004) and the Croatian state coordinate system HDKS inherited from the Austro-Hungarian Monarchy time (Bašić and Bačić, 1999). It is a unique GRID transformation for the entire area of Croatia, composed of the 7-parameter transformation

and predicted distortion value in the plane, as well as vertically (in a regular raster 603 x903), with 1780 at the moment available and reliable identical points in both datums used for it, the official Croatian geoid HRG2000 (Bašić, 2001), empirically derived covariance functions and collocation methods of least squares (schematically shown on Fig. 4). The final product is a user-friendly computer program T7D providing positional and vertical accuracy of transformation of ±10 cm at the entire territory of Croatia. Future expansion of this model with new data in some area will be more than simple and cause only local changes exactly in this area. The possibility of height transformation between the Trieste vertical datum and HVRS71 has been additionally built in.

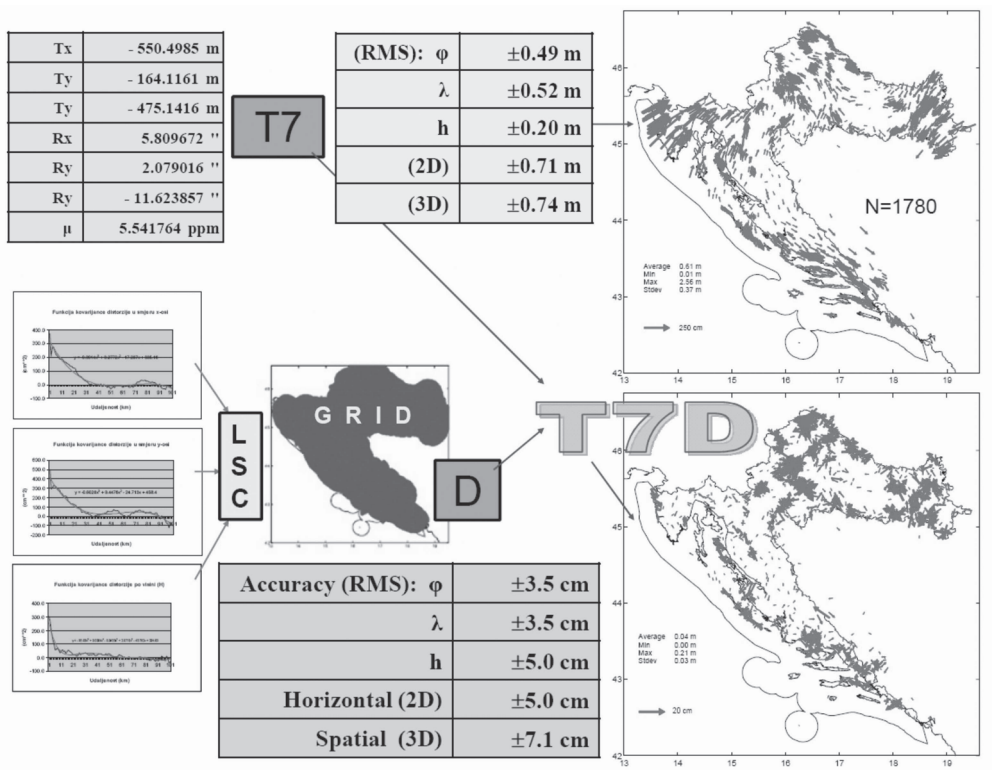

Fig. 4: *Schematic presentation of T7 (DAT_ABMO) and T7D model of transformation.*

The comparison of Gauss-Krueger coordinates established with T7D program with those obtained using DAT_ABMO program shows that as a rule one can expect differences at the edge of local areas (towns, county districts) up to two decimetres that have actually been the major problem so far, when only the 7-parameter transformation has been used. It should be pointed out that the transformation in both directions is possible with T7D, but the real one is the one that transforms geodetic coordinates from HDKS into HTRS96 (ETRS89), because it can be expected then to obtain a better quality of spatial data. The reverse direction, from HTRS96 into HDKS can be looked upon in some way as "ideal spoiling" of data that should normally be avoided. It can be

concluded that the new GRID transformation model, developed for usage in geodetic (and other) practice in Croatia, presents an essential step forward because it enables simple, efficient, quick and accurate transformation of spatial data, regardless of their quantity.

4 IMPLEMENTATION

Following the Decree (NN, 110/04), the director of SGA has announced a program for implementing new official geodetic datums and map projections on 4th of February 2005. Its purpose is to introduce the new geodetic datums and map projections into practical use on the entire Croatian territory, in all official registries and data bases and execution of work from SGA responsibility. Also, it aims to ensure the frame of the geodetic reference system of the Republic of Croatia for NSDI establishment creating necessary prerequisites and ensuring support for implementation of official geodetic datums and map projections in all official space referencing registries and data bases of governmental bodies and authorities as well as for economy and citizens. The program additionally should elaborate adoptions and use of necessary rules, standards and technical specifications and foresee the system of education and training to ensure its execution.

The implementation program defines necessary activities and tasks for the implementation of new geodetic datums and map projections in official use, modes and due dates of their performance, holders and subjects of their performance, and activities and measures that are to be undertaken by SGA in direction of implementing new geodetic datums and map projections in general use for all space information users, particularly on government bodies and public systems.

The program of implementation will be achieved by realizing a chain of tasks divided into few legislative, technological and organizational units:

- Fundamental geodetic works and state border survey,
- Topographic survey and state map production,
- Real Estate Cadastre,
- Registry of territorial units,
- Utility cadastre and engineering geodesy,
- Education and technical standard legislation.

Fundamental geodetic works: establishing of permanent GNSS-network of the Republic of Croatia – CROPOS (Fig. 5), establishing a unique positional transformation model HTRS96/HDKS and a new geoid model, the renewal and establishment system of maintaining ordinary geodetic sites of basic horizontal geodetic networks, check measurements of control networks, reconstruction of fundamental height network (by establishing new figures, its geometric configuration will be adjusted to the state territory and a systematic gravimetric survey will be undertaken), establishing a height transformation model Trst/HVRS71, completion of the fundamental gravimetric network and establishment of the second order gravimetric network, and finally, measurement and determination of coordinates of state border pillars.

The topographic survey: topographic data base transformation into the new projection coordinate system – HTRS96/TM and production of new sheets of topographic map TK25, digital orthophoto data base transformation into the new projection coordinate system – HTRS96/TM, transformation of Croatian base map (scale 1 : 5000) data base into the new projection coordinate system – HTRS96/TM and production of new sheets HOK5, setting up the terms (detailed algorithms for calculating and determined division by sheets) for constructing topographic maps in other official scales directly into the coordinate system of the new cartographic projection.

Real estate cadastre: generating conditions to perform a new cadastre survey in the new official geodetic reference system, cadastral map transformations of cadastre surveys that have been carried out within frame of the Program of state survey and real estate cadastre for the period 2001–2005 into new projection coordinate system – HTRS96/TM, transformation of cadastre maps that were produced in the old Gauss-Krueger projection into the new projection coordinate system – HTRS96/TM, transformation of cadastre maps that were produced by means of the graphical method of survey into the new projection coordinate system – HTRS96/TM.

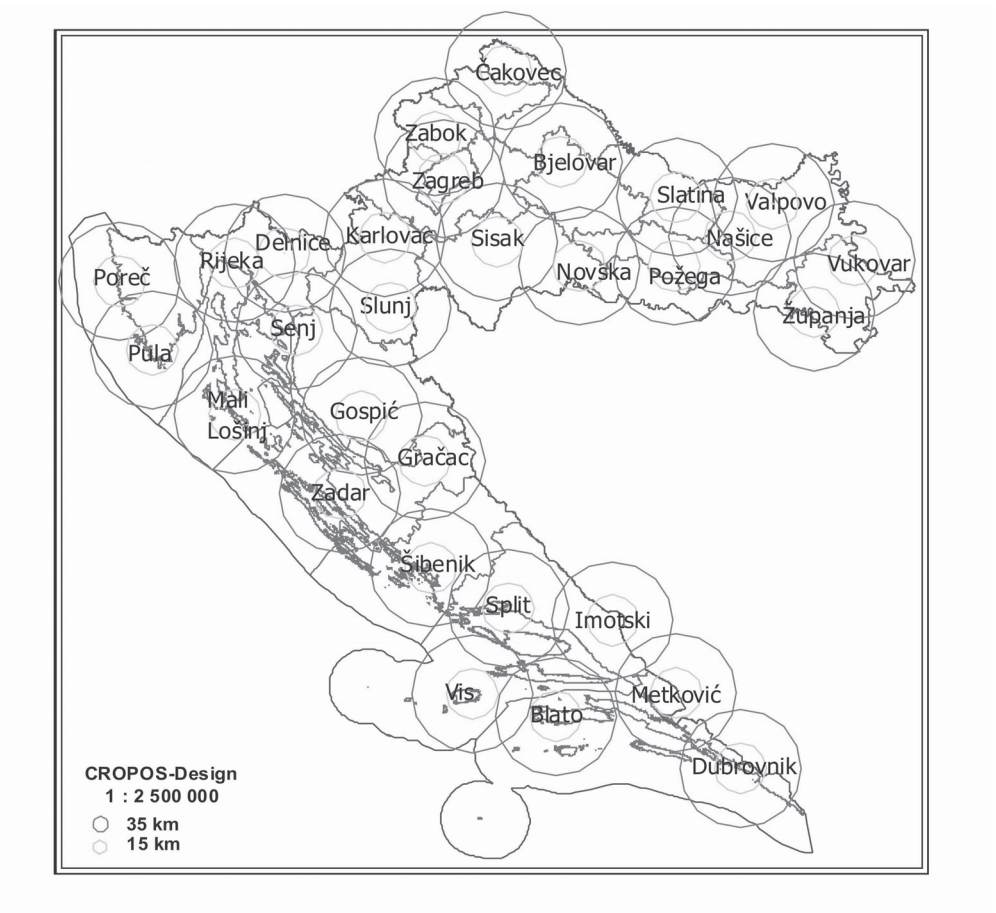

Fig. 5: *Design of the CROPOS reference GPS stations network.*

Central registry of territorial units: raster and vector data transformation of the central data base of space units into the new projection coordinate system HTRS96/TM, substitution of the existing raster data TK25 with appropriate data from the topographic data base.

Utility cadastre and engineering geodesy: informing the public by organizing seminars at the national level (annually) and regional level about introducing and implementing new geodetic datums and map projections, scientific and professional support to all governmental bodies, institutions and public systems in transforming their geo-referencing spatial data register into new geodetic reference system, providing the conditions for the performance of all geodetic works into the new official geodetic reference system.

Education and technical standards legislation: informing experts and the public through the existing publications ("Geodetski informator", "Vizura" and Catalogue of SGA products), as well as in the special brochures about introducing and implementing the new geodetic reference system, development and installation of implementation and application of new geodetic reference system modules into the system of education and training for geodesists, GIS and other experts, completing the book of rules denoting that the fundamental geodetic works will support the new geodetic reference system together with new acceptable and efficient methods of performing fundamental geodetic works, completing technical specifications of new map projections – HTRS96/TM for practical use.

The holder of the Program performance is State Geodetic Administration. The Program has been executed through Annual programs of State Geodetic Administration. The participants in the Program performance, besides SGA, are: Croatian Geodetic Institute, Faculty of Geodesy University of Zagreb, companies licensed to practice tasks of state survey and real estate cadastre and international institutions and competent organizations from other countries.

5 CONCLUSION

For the Republic of Croatia, the new official geodetic datums and cartographic projections have been defined. As a new positional reference coordinate system for the Croatian territory, European ETRS89 is adopted. The deadline for the implementation of the new geodetic datums and cartographic projections into official use is January 1, 2010. It will be a high tasking, complex and long-lasting work. Although the implementation represents a big challenge, it is also a big chance for SGA and all Croatian geodesists and surveyors to prove that we can build a new and modern geodetic reference system that will enable the completion of all users' requests.

Acknowledgment. The author is sincerely thankful to the Director of the State Geodetic Administration of the Republic of Croatia, Prof. Ph.D. Željko Bačić and the Assistant Director B.Sc. Marinko Bosiljevac, for submitting very useful information providing a significant support in preparing this paper.

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Prispelo v objavo: 6. november 2007
Sprejeto: 22. november 2007

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