

Development of Implementation of Geoinformation Provision of State Border Demarcation Works

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Introduction

According to world-wide generally accepted tradition, the term State Border Demarcation is used in the meaning “marking, installation of elements of State Border delimited in an intergovernmental agreement on the ground. In the framework of demarcation processes, location of the state border delimited in the State Border (delimitation) agreement is being exactly delimited on the ground, it is being fixed, marked and equipped with boundary markers and other marking elements on the ground. In the final stage, documentation of results of installation of this border is prepared - this documentation is called State Border demarcation documents.

When we get acquainted with the experience of Latvia in works of State Border re-demarcation – demarcation in the period after the restoration of independence in 1991, we can track development of experience of specialists and structures in the organization of geoinformation works, when they started works on Estonian border, continued them on Lithuanian border, further developed works on Belarusian border and finally fixed demarcation works on Russian border. Analysis of the experience gained has shown the impact of increase of knowledge and experience of experts involved on organization of performance of works, when demarcation of border with one country is completed and demarcation of border with next country is started, as well as the impact of the development of technical and technological solutions and of possibilities of the industry on measures and

works of geoinformation provision during all these years. While during the restoration of the first State Border - State Border with Estonia, the classical surveying methods and technical equipment prevailed, during the performance of the further border works, technical possibilities of state of art were implemented in the surveying, geodetic and mapping works. Finally, on the border with Russia, almost full-fledged use of Geographical Information Systems was started, use of possibilities of remote research increased considerably, it should be emphasized that contemporary GNSS tools and systems were used in order to determine spatial positions of border objects not only in the final stage – for the surveying of the border, but also for the geoinformation provision of all other works. Experience and development of technologies made a significant impact on the quality of the end results obtained, optimized extent of expenditures of the performance of works, as well as outlined significant or even revolutionary possibilities of further development for the further border maintenance measures. Research is based on experience gained in Latvian State Border demarcation or re-demarcation processes and geoinformation provision works with all neighboring countries in the period 1999 - 2017.

Materials and Methods

Based on experience of Latvian border demarcation, we can classify as geoinformation competence works those works, in the framework of which it is necessary to carry out works of geodetic and topographical surveying, and they are as follows: - Establishing of joint geodetic reference network of the border zone and surveying of the included geodetic points,

coordinate calculation;- Finding and preliminary marking of the designed (delimited) State Border line on the ground; -Marking and fixing of State Border on the ground; -Surveying and mapping of the State Border; -Technical and legal documenting of the State Border fixed on the ground according to provisions of the performance of intergovernmental agreement [1; 11].

When we get acquainted with history of creation or restoration of four demarcated State Borders after the restoration of the independence in 1991, we can observe unequivocal coincidence in the choice of performance of works and necessity to carry out them regardless the time of the performance of works, as well as real dynamics of the development of technologies of the performance thereof and of changes of conditions in the course of time. It should be taken into account that in this period from 1991 until early 2018, in industry of geoinformation in world, rapid and significant changes have taken place firstly in conjunction with the development of computerization and computer software, as well as with implementation of new technological and technical solutions in the performance of works of industry. The experience of establishing of State Border developed as follows – the first one was Latvian- Estonian State Border that was restored in the period from 1993 until 1999 [15]; – the second one was Latvian- Lithuanian State Border that was restored in the period from 1994 until 2000 [14]; – the third one was Latvian- Belarusian State Border that was restored in the period from 1997 until 2009 [13]; – the fourth one was Latvian- Russian State Border that was restored in the period from 2009 until 2018 [12]. The joint experience shows that in all cases, list of works of establishing of border was identical although the attitude, approach and technical solutions for the performance of works were rather individual in case of each border. Just the same applies to the geoinformation provision of these works.

For establishing of joint geodetic reference network of the border zone and surveying of the

included geodetic points, coordinate calculation; In the case of Estonian border, such network was not created - it was assumed that cross border network established during Soviet time in CK-42 is functionable still, and national networks of neighboring countries were created on the base of this former geodetic network data at the time of the installation of the border, the national geodetic reference systems of both neighboring countries were constructed from these data through mathematic re-calculations, therefore border surveying network was defined formally - list of points situated in the border zone was compiled, but re-surveying and measurement alignment works were not carried out [8]. Also approach to Lithuanian border is based on similar assumptions to those ones, which were used in case of Estonian border. The joint network was defined, lists of points (and coordinates thereof) were compiled through re-calculation of coordinates in both national systems [10]. Joint re-surveying and result alignment – calculation works were not carried out [8]. For Belarusian border, joint geodetic reference network creation works were started similarly through use of similar considerations, however not only the list of network points was compiled, but also in Belarusian side, some network points were created additionally or restored, they were surveyed, but calculations were made only in CK42 system [10]. For Russian border the joint commission changed the approach to conditions of establishing of the joint network and past practice – returned back to principles of establishing of classical geodetic reference system [5]. Change of approach was determined by experience of coordinating of border elements on previously installed State Border, which was negative so far. List of points of the joint reference network was not only compiled, but also operations of surveying of the base network and of joint calculation of their position – alignment were performed [9]. As base points of base network calculations, Latvian GNSS permanent function base stations were included from Latvian side in this network and one Russian side GNSS base station was

included as well [9].

Finding and preliminary marking of the designed (delimited) State Border line on the ground In the case of Estonian border, project of layout of border markers was compiled on the base of documents of border demarcation of 1920 [15]. Practical searching of borderline and locations of border points was based on visual searching of previously fixed elements of State Border or their remains by use of available cartographic, land-use planning and cadastre cartographic materials. Similarly these works were done in the cases of Lithuanian and Belarusian borders by use of previously prepared work map in scale 1: 10 000 [11]. In the case of these borders, in individual places, geodetic measurement methods were used for determination - searching of separate, ambiguously determined border sections or places or fixing thereof on the ground. Designed points for installing border markers were fixed with temporary border markers - wooden posts with anchors. Place of installment was fixed in working map (mainly visually) or by measurements up to landmarks and scheme (crock) of the point was compiled [7]. For Russian border, searching of locations of border line and border posts was performed based on the project of layout of border markers, which was developed and approved in the commission and depicted in the working map in scale 1: 10 000, but the initial search of points took place already by use GNSS hand navigation equipment – according to coordinates obtained from working map, where the really found location was depicted more exactly according to terrain situation elements found in vicinity at the end of search [12]. For the fixation of location, preliminary border posts – vista posts were installed, they were simple posts driven into the ground, which had a height of 1.5 m, without an anchor element [12]. Also in this case, the marked location was depicted in the working map and scheme of the location was compiled, but in this case, in the scheme, the coordinates (Breadth and Length – B and L) determined on the ground were written as the most important

element. Further these coordinates served as basic element for preparation of reporting documents in the demarcation commission (inclusion into working map) and for teams of erection of border posts – which used hand navigation equipment when searching vista posts.

Marking and fixing of State Border on the ground: In this stage of works, in case of Estonian, Lithuanian and also Belarusian borders, support of geoinformation sector was minimal, performers of construction works searched the erected preliminary border posts (according to schemes and working map) and planned works for purification of border line, compiled corresponding work execution and transfer acts [13; 14; 15]. Geoinformation experts carried out check of results usually already in the course of performance of next works. In the case of Russian border, locations of erected vista posts were searched by use of GNSS navigation equipment according to coordinates fixed in schemes – in acts of erection of border posts, coordinates of border posts obtained newly after the erection of posts were included, therefore participation of geoinformation experts was ensured in the entire course of works. These experts provided also preparation of work reports for commission by use of possibilities and advantages of GIS (Geographical Information System).

Surveying and mapping of the State Border: In cases of Estonian, Lithuanian and Belarusian borders, surveying of State Border was organized according to border sections, for which countries are responsible, and in this case, control was provided by the other part approximately in extent of 10% out of all the measurements [13; 14; 15]. Conversion of the coordinates obtained into coordinate system of neighboring country was carried out in accordance with mutually agreed conversion algorithms, where, in case of mutual checks, deviations should not exceed the agreed values (they were ± 0.3 m usually). In the case of Estonian border, surveying was organized by use of classical theodolite moves and only in

final check works, professional GPS tools were used [8]. In the case of Lithuanian and Belarusian borders, mainly contemporary GPS technologies with coordinate correction in post-processing processes were used, in individual border sections (where limitation of the open horizon were present), theodolite moves formed by tachometers were included in works [2; 3]. Taking into account the negative experience of Estonian border with accuracy of coordinates – it was required in the surveying of Lithuanian border in one session of surveying works to use reference points in territories of both of countries mandatorily. In the case of Russian border, coordinating along land border sections was carried out by both parts in full extent – without parts of responsibility, along watercourse each part surveyed in its respective shore and control measurements were provided by measurements of the other shore in extent up to 10 % out of surveyed points [12]. Taking into account that both parts used one joint coordinate system for the surveying of Russian border, which was fixed and mutually checked, when the joint geodetic reference network was created, coordinate transformation operations and coordination of transformation algorithms were not necessary. In the performance of works, both parts based mainly on use of GNSS receiver systems - including the massive application of real-time correction services from the geodetic base station system operating in Latvia [5]. For individual surveyings of border sections also moves of tachymeters or total stations.

Compilation of Demarcation Map for Estonian border was carried out with financial support and involvement of experts of Denmark. Base of the map was created in version of Digital Data – simplified vector data (DGN – format) [15]. Latvian and Estonian specialists did not know the technology of producing such maps at that time, and it was a time of creativity for the Danish experts in this field, therefore the results of the work did not reach a good quality and the work was delayed. In the final stage of works, Latvian and Estonian experts themselves were

able to carry out data correction. For Lithuanian border, works on the development of demarcation map were started in the final stage of demarcation works – rather late. In order to observe the politically defined demarcation completion deadlines, experts managed to get consent to develop the border demarcation map as photo map, where mapping activities were attributed only to State Border and elements related to it. The decodable elements were created in digital vector data format by use of GIS (geographical information system) software (Arc GIS), which allowed the mapping process to be completed within a very short time - within a year.

In the case of Belarus and Russia, the neighboring countries did not agree with the deviations of the visual design of the map from the classical requirements, therefore, their development required to comply with the requirements for full-fledged mapping specification, although in practice all the parties used contemporary vector data development technologies, regardless of which software was used by each of the parties [1]. In both cases, the development of map bases was started already in time (in contrast to the case of Lithuania) - even when the border installation works were in their execution processes. The coordinates of border markers on the maps were entered from the measurement data. The development of the Russian border map was greatly facilitated - as the map was designed by use of only a single coordinate system, and only a single coordinate system was depicted there [4]. Similarly, the placement of place names in the territories of neighboring countries was streamlined in such a way that it was not necessary to make changes in the legend on the map, when map versions in alternative languages were produced [4].

Technical and legal documenting of the State Border fixed on the ground according to provisions of the performance of intergovernmental agreement: The sets of documents for cases of all borders were mainly similar, the differences in their volumes were

more dependent on the length of the borders and on the rules of the use of alternative languages.

Results and Discussions

By systematizing the Latvian experience in demarcation work on time expansion - in the table (Table 1), we can conclude that the experience acquisition period is more than twenty years and the works on individual borders were performed sequentially one after other. The first borders are Estonian and Lithuanian borders, where the times of commencement and completion of works differ only for a year. Regardless of the fact that the length of Lithuanian border is greater than that of Estonian border almost two times - the execution time for the two borders is almost equal, i.e., about 7 years for each border. Practically, the overlapping of works here points out that between these boundaries - in the

performance of their works - there could be no significant difference between technological and technical solutions, nor can there be a significant increase in the experience of the involved specialists. Another situation arises with the next two borders. The Belarusian border - the beginning of demarcation coincides with the completion of g works with the previous two borders, when the problems and their causes that were caught up in the previous period were not fully understood, but in the course of ten years, optimal solutions for them have been systematically and timely looked for. The Russian border - whose demarcation time begins at the end of the demarcation of the Belarusian border, when the understanding and forecasts of possible demarcation problems, as well as the perspective of the best solutions, are already prominent.

Time schedule of executing of Latvian State Border demarcation works

table 1

Country \ Years	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Periods of demarcation works																										
Estonia																										
Lithuania																										
Belarus																										
Russia																										
<i>Establishing of geodetic networks</i>	E	L					B	B											R							
Determination - marking of border line																										
Estonia																										
Lithuania																										
Belarus																										
Russia																										
Marking and fixing of State Border on the ground																										
Estonia																										
Lithuania																										
Belarus																										
Russia																										
Surveying and mapping of the State Border																										
Estonia																										
Lithuania																										
Belarus																										
Russia																										
Technical and legal documenting of the State Border fixed on the ground according to provisions of the performance of intergovernmental agreement.																										

in the project and automated fixation of the location in the selected coordinate system. Such data gathering in combination with the use of modern GIS software enabled the rapid and accurate reporting of results and the preparation of working materials for border installers. In addition, the marking of a border with temporary border posts could now be carried out after a simplified performance - it became cheaper, as well as faster. Much more effective was the development of solutions for unclear or controversial border sections, where the GIS enabled high-precision interconnecting of various cartographic materials (both historical and contemporary land surveying, as well as various aerial or space images) into a single spatial analysis document and to prepare datasets for draft proposals for rapid and accurate use on the ground by means of GNSS navigation or measuring equipment.

Marking and fixing of State Border on the ground greatly improved and accelerated the possibility to find flawlessly the designed project by use of GPS hardware, which was implemented on the Russian border. This equipment greatly improved the preparation of reports and the rapid implementation of their results in cartographic material by use of GIS capabilities, both for the organization of inspections, for quality assessment, and for the development of future demarcation documents.

There were also many and significant changes in the technologies for surveying and mapping of the State Border, as well as in technical and legal documentation of the State border along with changes in the creation of geodetic support. In the beginning, when check of the surveying of the Estonian border was organized - it was professional GNSS equipment, which changed the efficiency of work. On the next borders, the use of the possibilities of this equipment has developed - expanded. Already on the Lithuanian and Belarusian borders, most surveys were carried out by use of GNSS equipment and technology. The performance of the remaining theodolite moves was changed - at the beginning, the use of geodetic

tachymeters has improved it and later, use of total stations replaced them. And finally - RTK (real-time correction) possibilities were used maximally in the GNSS measurements of the Russian border - this was ensured by the system of permanent base stations in Latvia.

In general, there is a finding that the practice of state border demarcation in the case of Latvia indicates significant changes in the development of used geoinformation provision technologies over time and when moving from one border to the next. Application of the latest technological and technical solutions and changes in development, their implementation in state border maintenance activities will be the next stage of experience and challenges for Latvian geoinformation specialists. The revolutionary changes of geoinformation technologies, which have taken place until now and will be taking place in the future, their potential and influence, offers a significant overhaul of past practices and requirements for the organization and results of border demarcation and maintenance work.

Conclusions

1. The practice of state border demarcation in the case of Latvia indicates significant changes in the development of used geoinformation provision technologies over time and when moving from one border to the next;

2. The changes of geoinformation technologies, which have taken place until now and will be taking place in the future, their potential and influence, offers a significant overhaul of past practices and requirements for the organization and results of border demarcation and maintenance work;

3. The experience of Latvian specialists on the ground of the geoinformation provision of state border installation can be considered as very serious at both regional and international level. In the future, the lessons learned can serve as a collection of theoretical and practical experience for demarcation work experts from other countries;

4. The experience gained, demonstrating the possibilities of introducing modern geoinformation technologies and practices in

demarcation and border maintenance work, reinforced the conviction that there is a need to plan and implement the work of this provision in the future as mutually integrated measures;

5. In addition, conclusion was made that it would be useful to coordinate these works in the future with a range of works of national competence, such as alienation of real properties, creation of a border zone, and putting of cross-border drainage systems in order.

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**DEVELOPMENT OF IMPLEMENTATION
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WORKS**

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The paper describes participation of Latvian geoinformation field specialists in the process of

determining the determining the state borders after the restoration of independence in 1990. The determination of the state border resulted in considerable practical and theoretical experience. Demarcation works took place over a considerable period of time from 1991 to 2018 on four land borders of the country. Experts had the opportunity to experience and appreciate the significant development of the technologies used in the geoinformation technology, moving from one state border to the next. The paper deals with the history of the involvement of the latest geoinformation technologies and technical solutions in the processes of Latvia state border restoration and analyzes the impact on the parameters of the demarcation work implementation.