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New topographic maps for the Czech Armed Forces

Václav Talhofer [a,*], Luboš Bělka [b], Filip Dohnal [a]

[a] *University of Defence in Brno, Faculty of Military Technology, Department of Military Geography and Meteorology, 1st Author – vaclav.talhofer@unob.cz, 3rd Author filip.dohnal@unob.cz*
[b] *Office of Military Geography and Hydrometeorology, Dobruška, 2nd Author – lubos.belka@vghur.army.cz*

* Corresponding author

Abstract: Geographic services of NATO member states produce standardised topographic maps for geographic support of their foreign missions. The MGCP data are used for the maps creation of the scales of 1:50,000 and 1:100,000. Topographic maps used for military training in own territory mostly remain in original form without full standardisation. NATO with support of the Defence Geospatial Information Working Group prepares a new standard for the Defence Topographic Map. The geographic service of the Armed Forces of the Czech Republic has started the preparation process of the new topographic maps edition compliant with the new standard. Two prototypes of map sheets of scales of 1:25,000 and 1:50,000 were created in 2020, which serve for basic verification of map content symbolisation and applied technology. Procedures for generalization of the map content for the scale of 1:100,000 will be completed in next two years.

Keywords: topographic map, NATO standard, generalization, cartographic model

1. Introduction

For a long time now, the North Atlantic Treaty Organisation (NATO) has been working under the motto "fight off the same map" to unify the means of expression of maps used in joint operations of the NATO allies. In 1983, the Defence Geospatial Information Working Group (DGIWG) was established as a multi-national body to provide strategic guidance and recommendations to its membership on the standardisation of geospatial data, products, and services (DGIWG, 2020). Many documents have been published since DGIWG was established which have served as main sources for Standardization Agreements (STANAG) issue.

In parallel with standardisation activities, international projects initiated by defence community and focusing on geospatial data collection have been realized. The Multinational Geospatial Co-production Program (MGCP) started in 2003 as a continual successor of previous Vector Map (VMap) project. The main aim of the MGCP is to collect geospatial data from crisis areas in density corresponding with a topographic map of scale 1:50,000 and 1:100,000. Technical Reference Documentation (TRD) (MGCP, 2012) provides an unambiguous extraction guidance for the data collection.

MGCP data and derived topographic maps are used for geographic support of allied armed forces in foreign missions. So-called MGCP Topographic Maps (MTM) are created according to the Data Product Specification (DPS) 1:50,000 and 1:100,000 scale MGCP Topographic Map (MGCP, 2017). The specification standardise:

- map sheets dimensions,
- map frame template including legend,
- map content,
- symbology,
- comprehensive instruction for each feature symbol usage (placement instructions, component instructions, generalization, label placement, and finishing rules).

Soldiers of NATO countries meet these topographic maps during their foreign missions as a basic localisation source. The maps are used by land and air/rotary forces in support of ground operations, for planning and execution of tactical operations, land navigation, and fire support missions to provide basic terrain analysis information to assist in the Intelligence preparation of the battle space through a standardized graphical representation (MGCP, 2017).

The success of MTM usage in foreign missions strongly depends on previous military training at home. And there is a problem as national military topographic maps are not usually standardised and their design and content vary from one NATO member state to another. In fact, only geodetic reference system World Geodetic System (WGS84) and Universal Transverse Mercator (UTM) projection are often standardised while map content, symbology, and cartographic quality differ. Some military mapping agencies use own geographic data standardised according to NATO STANAGs, some of them use civilian topographic (state) maps, which are supplemented by standardised elements.

While standardised MGCP data are collected from abroad, geospatial data from the NATO member states´ own territory are in principle not standardised yet. To reach a real interoperability, it is highly recommended to all member states to publish standardised data also from their own territory for

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military purposes, especially for a field training. The standardisation agreement STANAG 2592 The NATO Geospatial Information Framework (NGIF) (NATO, 2018) defines main principles of this standardisation, feature concept, and feature dictionary. NGIF will include also a product specification for a military topographic map at a scale of 1: 50,000 soon, so-called Defence Topographic Map 1: 50,000 (DTM50), coming from the MTM specification. The DTM50 specification is almost completed and expected to be adopted during 2021 (stage in December 2020). Further progress in its adoption will depend on the decision of the member states and their national geographic agencies and services.

2. Approach to standardisation of defence topographic maps in the Army of the Czech Republic

Military topographic mapping has a long tradition and history in the Czech Republic (CR) and in Czechoslovakia previously. In 1950s, military topographic service created new topographic maps strictly standardised within the former Warsaw Pact. Regardless of the political context, the maps represented a high-level cartographic quality. Topographic maps of all scales had the same geodetic system (S-1952, later S-1942 – Pulkovo), projection (Gaussian), system of map sheets and their numbering, map sheet template and fully standardised map content and its symbolisation. The main characteristics of these maps, whose four editions were published, had remained the same until the Czech Republic joined NATO in 1999.

However, the implementation of the NATO standards had already begun before the Czech Republic joined NATO. Initially, geospatial standards were applied to the main geospatial data model - the Digital Model of Territory DMU25 (MoD-GeoS, 2013) - and the fourth edition of the topographic maps was supplemented by standardisation elements such as UTM grid in WGS84.

The first edition of standardised topographic maps according to NATO was published in 2006. WGS84, UTM projection, Military Grid Reference System (MGRS), and bilingual legend (Czech and English) are the main standardisation elements. As no STANAG dealing with the map content and symbolisation existed, these aspects remained the same as for previous editions. Also, DMU25 has remained as a basic data source for cartographic models until today.

2.1 Current map creation

The Office of Military Geography and Hydrometeorology (OMGHM) is responsible for the whole technology of current topographic maps creation. As stated above, DMU25 is the basic data source, in which all features are classified according to Catalogue of Topographic Objects (MoD-GeoS, 2013) corresponding to DGIWG Feature Data Dictionary DFDD (DGIWG-500, 2010).

DMU25 is also the basic data source for the cartographic models of the topographic maps whose content, symbolisation and generalization rules are defined in the regulation Topo-4-5 (MOCR, 2008). ESRI ArcGIS software suite and its tools are used for own solution of the automatic cartographic model derivation including various procedures of the map content generalization and symbolisation. However, the process of maps creation still demands manual finalisation

The 3rd edition of the standardised topographic maps at scales of 1:25,000, 1:50,000, and 1:100,000 is being finished at the time being.

The solution has many advantages:

- using of own data source including system of data collection and data editing;
- the data is ready for the cartographic model derivation directly as features are classified and encoded according to Catalogue of Topographic Objects having all required attributes, and no reclassification of the attributes is necessary.

The main disadvantages include the following:

- demanding a lot of human work,
- amount of human work does not allow to save the limited capacity of OMGHM,
- limited standardisation, mainly the map content and map symbols are not standardised.

After extensive discussion and consideration of the pros and cons, the Geographic Service management decided to move to fully standardised topographic maps compliant with the DPS for DTM50 (DGIWG, 2020) starting from the next edition. As stated in the introduction, this specification is now being finalized by the DGIWG. Due to its current unavailability, the specification for the MGCP Topographic Map has been used for the time being, which mostly corresponds to the DTM50 in terms of map appearance and cartographic means of symbolisation.

At the same time, in order to optimize production capacities of OMGHM, it was decided to use the civil database ZABAGED (CUZK, 2020) as the basic data source for the future defence topographic maps production.

The Fundamental Base of Geographic Data of the Czech Republic (ZABAGED) is a digital vector geographic model of the territory of CR, which is administered by the Land Survey Office in the public interest. ZABAGED is a part of the Information System of Land Surveying. It is used as a base layer in geographic information systems (GIS), primarily in information systems of the public service. It also serves as the main data source for creation of civilian

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state maps of CR at scales of 1:10,000 to 1:100,000. Currently selected feature types of ZABAGED are used for the INSPIRE data structure (CUZK, 2020).

2.2 New edition of defence topographic maps

The fundamental differences between current topographic maps and future full standardised DTM can be described as:

- new spatial extent of map sheets and their system of numbering,
- new map design and style of portrayal including the arrangement of marginalia,
- new colour schema,
- different map content,
- different classification for many features in the map content.

Users have to get familiar with the changes in the feature classification and symbolisation, especially for roads, build-up areas and vertical obstacles.

Current classification of roads reflects mainly their technical characteristics – importance, surface material, width etc. In the new concept, the emphasis is put on the performance characteristics of roads. Moreover, the roads can be taken into account as potential obstacles for cross-country movement. Symbols for the roads express their administrative division (primary and secondary), presence of vertical median barrier, number of lanes, and load bearing surface type. Dark brown colour has been chosen for roads symbols to enable reading them during worse light conditions and under red light.

According to the new concept, build-up areas are divided into dense and sparse (or moderate) blocks. Only dominate or important buildings will be shown in build-up areas at the scale 1:50,000. The emphasis is put on the street network in built-up areas. At the scale 1:25,000, a higher number of buildings will be portrayed in build-up areas.

Because the DTM will be used for air/rotary forces in support of ground operations, objects higher than 46 m have to be portrayed as vertical obstacles. Symbols for the vertical obstacles and airports are unified in most of NATO maps and charts (specific shape and air-blue colour) therefore the same system has been incorporated into this specification.

Relatively significant changes will be in the use of geographic names and labelling. All labels but toponyms will be in English. English is the primary language in a legend while Czech is the secondary language.

Almost all 2020 year was devoted to verifying the use of a different data source other than the current DMU25 for the DTM creation and for the preparation of the prototype of 1:25,000 and 1:50,000 scale. The research team mostly consisted of specialists coming from OMGHM belonging to the Geographic Service of the Armed Forces of the Czech Republic, supplemented by academic staff of the University of Defence in Brno.

The team had to deal with the following issues:

- transformation of ZABAGED data model to a new military data model (called the Military Model of Territory – MMT), identification of missing attributes and their population from other sources,
- DTM DPS implementation for the MMT using ArcGIS Pro software, primarily resulting in the cartographic model for the DTM 1:25,000 scale (DTM25),
- further generalization of both the MMT and the DTM25 content resulting in the cartographic models for 1:50,000 and 1:100,000 scales (DTM50 and DTM100),
- verification of created tools and generalization procedures for typical landscape types.

2.2.1 *Transformation of ZABAGED to the Military Model of Territory*

MMT will be derived from ZABAGED data model and used for the new topographic maps creation and also for other military purposes. ZABAGED features are delineated with higher geometric resolution than required even for the 1:25,000 scale maps. Moreover, ZABAGED uses different characteristics than required for DTM. Some attributes are missing, some are extra. Therefore, it is necessary to modify ZABAGED data model according to the new data model requirements. Geometric detail is retained in MMT, but missing attributes are necessary to populate from others sources such as the Information System of the Directorate of Roads and Motorways - IS DRM (DRM, 2019). It provides information about roads construction such as median existence and its type, width, number of lanes, etc.

The resulting MMT will be fully compliant with the NATO digital geographic data standard prepared for geographic support of ground and air/rotary join operations within NGIF (NATO, 2018). Creating of the DTM is only one example of its user application.

2.2.2 *DTM DPS implementation for MMT*

Cartographic model of DTM is symbolised by future NATO standard DTM DPS (DGIWG, 2020), which is under final comment procedure (January 2021). The specification defines very clearly all symbols, their dimensions, shapes, structure, colours, and rules for generalization, finishing and label placement. The implementation of the standard is already in the competence of an organization responsible for the maps production. ESRI products are traditionally used for many tasks in OMGHM, therefore ArcGIS Pro was chosen as a fundamental tool for the DTM production.

Most of the standard symbols have been used for prototype creation, but according to the opinion and experience of the researchers, some symbols do not

correspond to the character of the geographical environment of Central Europe or they are not legible enough. Thus, several symbols have been modified and these proposals for symbols modification will be send to DIGWG. In the table (Table 1) are some of them.

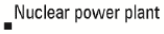
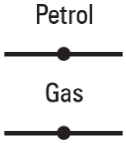
Feature	Standard	Proposal
Power Line	One symbol for all feature without label (voltage) 	Two categories divided according to voltage (≥220 kV; ≤110 kV) 
Power Station, Power plant	General building with a label 	Different symbol (answer to present topographic maps) 
Aeronautical obstacle (smokestack)	General symbol aeronautical obstacle with a label 	Specific symbol – enlargement of smokestack symbol and different colour (air-blue) 
Pipeline	Breakdown by product (label) 	Breakdown by product (symbol) 
Tree line (Line of trees)		

Table 1 Proposals for symbols modification (examples)

2.2.3 *Generalization*

Members of the research team have an extensive experience in the field of cartographic models' derivation from GIS data models and systems of map content generalization and visualization. For previous editions of topographic maps, they prepared several complex workflows using ESRI ARC/INFO and ArcGIS software suites. However, all the previous technologies used own (in-house) data.

Usage of the MMT requires quite a new approach in the field of adding missing data as well as in the field of generalization. Data density and accuracy of ZABAGED corresponds to approximately 1:5,000 scale therefore generalization procedures have to be applied for the DTM25. Further generalization procedures are and will be created for the 1:50,000 and 1:100,000 scale cartographic models. The team intends to reduce a manual cartographic finalisation. Both previous experience and cartographic tools incorporated in ArcGIS Pro give a big chance to fulfil this idea. However, based on the prototype creation experience, it seems unavoidable to refine some content manually. Several new approaches published at universities and journals, e.g. ISPRS International Journal of Geo-Information or Geoinformatica, are also very important sources for creating generalization processes. Especially the dissertation thesis by Vetter (Vetter, 2014) and Lysák (Lysák, 2016) give inspiration for these new approaches.

2.2.4 *Verification of complex solution*

When creating DTM content from the area of the prototype map sheets at a scale of 1: 25,000 and 1: 50,000, which were located between Hradec Králové and Pardubice, many basic solutions were developed and verified. However, the complex solution, especially the setting of generalization and visualization rules, still remains for further development steps, including deep verification of the complex solution. The setting of the rules of generalization and visualization will be verified in typical landscape types in the Czech Republic. Eleven landscape types were selected for this verification, from dense industrial and urban zones on the one hand to sparsely populated landscapes on the other. The table (Table 2) shows the main characteristics of the selected landscape types.

Geographic location (in Czech)	Main landscape characteristic	Reason for choice
Oloví	Highlands with forests and meadows	Foothills and mountainous relief.
Praha	Urban and industrial agglomerations	Concentration of residential and industrial buildings, high density of roads of various types, complicated expressions of the character of buildings and the whole locality.
Opatovice nad Labem	Lowland landscapes	Flat (plane) landscape with a dense network

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Geographic location (in Czech)	Main landscape characteristic	Reason for choice
	with settlements	of roads of various types with rural and industrial buildings.
Dolní Zálezly	Deep valleys in highlands	Vertically richly rugged landscape with a concentration of roads, settlements and watercourses in a narrow breakthrough valley. Challenging to display the accumulation of these objects.
Stříbřec	Pond landscape with woods and meadows	Pond landscape with a large number of water areas, typically ponds. The need to preserve the character of the landscape.
Duchcov	Opencast mining landscape	Intensively used landscape for opencast mining with a number of industrial areas and remnants of completed mining. Complicated expression of proportions between the original landscape and its changes due to mining activities.
Havlíčkův Brod	Agricultural landscape in highlands with smaller cities and villages	A dense communication network with a significant railway junction and a dense network of power lines. In Havlíčkův Brod, the occurrence of

Geographic location (in Czech)	Main landscape characteristic	Reason for choice
		most types of structural development of the post-socialist city. Challenging to capture the character of the site.
Jičín	Agricultural landscape with forests and rocky towns	A large number of diverse relief shapes of natural and artificial origin in relation to the cultural landscape. A challenging way to display the character of the landscape.
Morávka	Highland landscape with very sparse settlements	Mountainous forested landscape with scattered buildings in the valleys and on the slopes. Verification of the way of displaying especially the buildings while maintaining its character.
Velké Bílovice	Agricultural landscape mainly with vineyards, sparse settlements	Wine region in the lowlands. Verification of the way vineyards are displayed as artificial obstacles to movement.
Valtice	Agricultural landscape on the state border	Wine region with forests, wetlands and ponds on the state border. Verification of the method of geographical objects symbolisation and state borders with

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Geographic location (in Czech)	Main landscape characteristic	Reason for choice
		possible verification of compatibility of MMT data based on ZABAGED data model and supplemented data from abroad made by OMGHM

Table 2 Main characteristic of chosen landscapes for generalization rules verification

2.3 Achieved results

The technology of the DTM production has not been finished yet, but the main goal of the transformation to full NATO standard was carried out in 2020. Usage of non-standard data model ZABAGED was approved, and also usage of MGCP topographic map symbols, resp. DTM symbols in ArcGIS Pro proved to be applicable. Figure 1 shows a difference in the symbolisation of the current topographic map of 1:50,000 scale and the DTM50 prototype.

a) b)

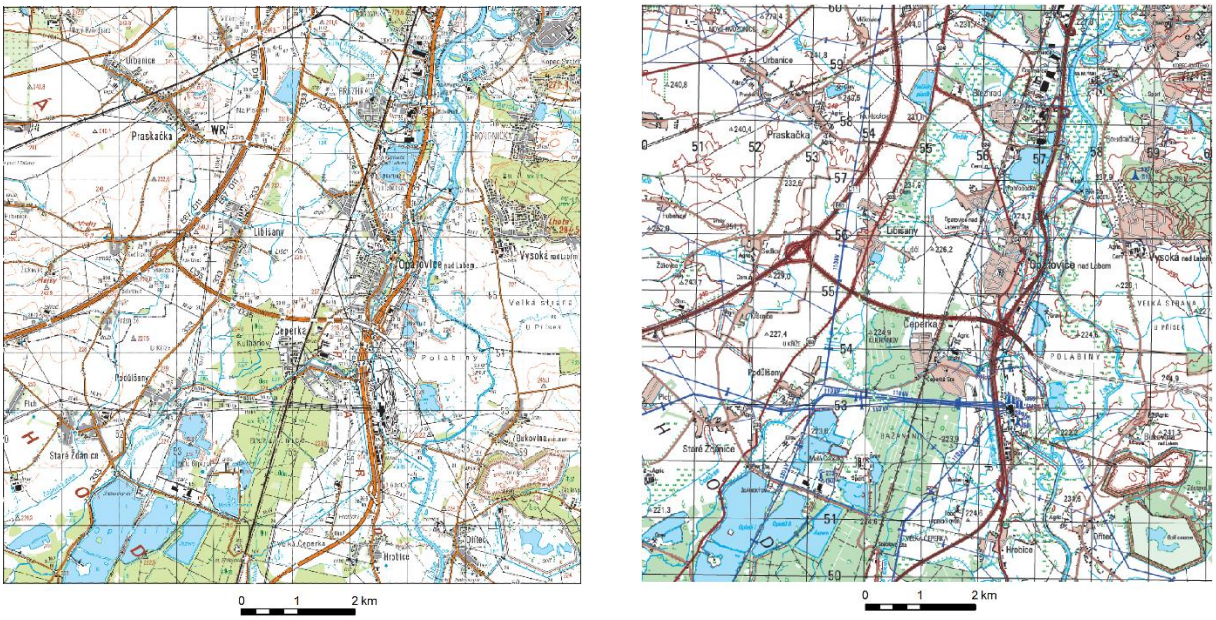

Figure 1 Comparison of the current topographic map (topicality of database content by 2017) - a) and the prototype of the new defence topographic map (topicality of database content by 2020) - b)

Despite the incompleteness of the technology, it is possible to state that the new topographic maps have positive aspects such as:

- broader user application, e.g. the map usage by air and rotary forces performing tasks in support of ground forces;
- legibility under red light, which expands the possibility of the map usage in difficult lighting conditions. This was tested and results proved, that the main elements of the map are clearly legible, including hypsometry;
- larger format of the map sheet improves users' situational awareness, when a user has an overview of a larger area without the need to have more map sheets. Moreover, in comparison with current technology, a larger format of the map will allow reduction of the map content harmonisation of adjacent sheets which increase the efficiency of the map production.
- the map content is reduced compared to the current topographic maps. Especially very fast changing features like cart tracks, or some technical details about roads, bridges etc. are reduced and thus the whole map content becomes obsolete more slowly.

3. Discussion

Several issues regarding the technology still remain unresolved:

- extension of the MMT with additional features, attributes and attribute values to ensure all required map objects. Moreover, applicability of external data source is always an issue. Regarding ZABAGED as a basic civilian database, the team had to cope with a different classification, definitions of objects and semantics than required by military standardisation. Thus, there is a need of transformation (feature mapping) between ZABAGED coming into

the MMT and a structure compatible with NGIF.

- automation of the generalization procedure – a set of cartographic models covering all three scales will be created;
- incorporation of user requirements coming from their testing. Applicability of the map have to be proven by users. It is necessary to make various tests in different field conditions and by a wide range of military units.

The team has gained experience with a practical implementation of the standard which justifies potential change proposals. Clear arguments supported by the prototype will be put on the table to enforce them. The aim has been to thin out the map mostly by reduction of labels. In the end, a positive feedback may improve the standard itself.

4. Conclusion

The change of the topographic map production is a significant step forward to increase interoperability among NATO allies. The Czech cartography has a long tradition and the team is trying to keep this high level within the standard implementation and struggling to create a high quality cartographic work. Moreover, the new maps should also bring significant benefits for their military users.

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