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## Using GIS and historical digitized aerial imagery and maps to analyze information on Cold War Soviet military maps of Denmark

*Keywords:* Topographic maps; Warsaw Pact; NATO; Geospatial Intelligence

*Summary:* During the Cold War, the General Staff of the Soviet Union secretly mapped foreign countries for military purposes. As the material was unavailable to scholars before the fall of the Soviet Union, research into the cartographic heritage of this global mapping enterprise has only emerged in recent years. The geographical information contained in the maps was based on a wide range of sources, among them remote sensing, existing topographical maps and even information collected by intelligence officers in the field (Davies and Kent 2017). Davies and Kent have carried out pioneering work on the Soviet practice of mapping, but mostly based on material from the United States and the United Kingdom. Following the research agenda set by them, this paper presents an initial analysis of the Soviet military mapping of Denmark based on the collection of Soviet maps held by the Royal Danish Library. We focus on identifying information sources used in production, as well as assessing the general cartographic quality of the maps. Our approach is a GIS-based investigation of the origin of the topographical information on Soviet military maps, utilizing an extensive collection of more than one million geo-located historical aerial photographs along with a collection of digitized topographical maps covering all of Denmark throughout the period of study. The method consists of the following steps: (1) Scanning and geo-referencing of the Soviet military maps, (2) guided selection of areas/map sheets to be included in the analysis, (3) examination of the geometric, positional and thematic accuracy of Soviet map objects, and (4) an assessment of the quality of information in the Soviet maps based on contemporary aerial imagery and possible identification of the source of information used in the maps.

### Introduction

Denmark was one of the frontline states in Europe during the Cold War. Facing the Iron Curtain in the Baltics, the country was subject to a significant attention from the Warsaw Pact intelligence agencies. This included the gathering of geospatial intelligence covering Danish soil (Hillingsø 2004; DIIS 2005; Laursen 2009). The sheer extent of the global Soviet mapping project serves well to indicate the ambitions of intelligence gathering in Warsaw Pact countries (Davies and Kent 2017). As a result of the comprehensive effort, topographical maps are preserved in various scales for most parts of the world as well as large-scale maps of many major global cities. Although there has been a significant interest in Cold War history in general as well as a particular interest in the history of Cold War intelligence gathering in Denmark, the cartographic material produced by the Soviet Union has been left mostly untouched, aside from minor enquiries on Danish map production and the efforts to protect geospatial information (Stenak 2013). Internationally, there is a growing scholarly interest in the Soviet mapping projects during the Cold War, especially focusing on the Soviet mapping of United Kingdom, the United States and Ireland (Davies and Kent 2017; Kent and Davies 2013; Travers 2008). This focus on the

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cartographic heritage from the Cold War provide a much needed framework for analysis of the maps, which paves the way for detailed studies of the Soviet mapping practice in different countries around the globe. Digital methods and extensive research infrastructure has become increasingly available in recent years, which has allowed scholars in the field of cartographic heritage to step into a new age of digital research. Digital tools for analysis of cartographic material such as GIS have now been supplemented with large collections of digitized historical cartographic material and aerial imagery, providing a comprehensive digital record of historical spatial information. This is certainly the case in Denmark, where both historical topographical maps and historical oblique and vertical aerial imagery have been digitized and made freely available as high-resolution image data. Thus, our aim with this paper is to evaluate the use of GIS and comprehensive digitized heritage in the form of historical geospatial information to analyze the quality of the content of the Soviet mapping of Danish territories, as well as the origin of the spatial information contained in the Soviet maps.

### **Methods and materials**

This section presents our analytical framework, the data the use to assess the accuracy and source of information and our selection of study areas to exemplify our approach to of the large-scale Soviet topographic maps and city plans.

#### *Soviet maps of Denmark*

The secret Soviet military maps became widely available on the free market in the early 1990s following the collapse of the Soviet Union. The Royal Danish Library first acquired them as they became available in the 1990s. However, in 2017 the library supplemented its holdings with additional city plans and topographic maps of the Danish island Bornholm in the Baltic. Generally, the collection holds only a single edition of each map, typically printed in the 1980s. There are exceptions to this, as some topographical maps are held in several editions, including a plan of the major Danish city of Odense. But in general terms opportunities to study variance between map editions are limited. Selected Soviet maps from the collection were digitized and georeferenced. Text bits noted on the city plans, containing information on the map and its contents were extracted using a free online ORC service<sup>1</sup>. The Russian text was then translated using Googles translating service ([translate.google.com](http://translate.google.com)). We found the result of this approach to be sufficient to provide us with a workable list of objects, although the translation was very crude and inaccurate.

#### *Identifying case areas and selecting the Soviet maps*

In order to identify interesting cases to test our approach, we decided to focus on now well-known sites of military importance, such as major NATO facilities and sites for a projected amphibious Warsaw Pact assault on Zealand (Hillingsø 2004). On the large-scale topographic maps, we chose the Faxe Bay in southwestern Zealand, which was a main site for a potential invasion, and the area around Jyderup in northwestern Zealand, the main supply area for Danish forces on Zealand.

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<sup>1</sup> <http://www.i2ocr.com/free-online-russian-ocr>

The latter also holds several depot facilities. Of city plans we focused on the capital city of Copenhagen, as we suppose the Soviet agencies had a natural interest in the Danish capital.

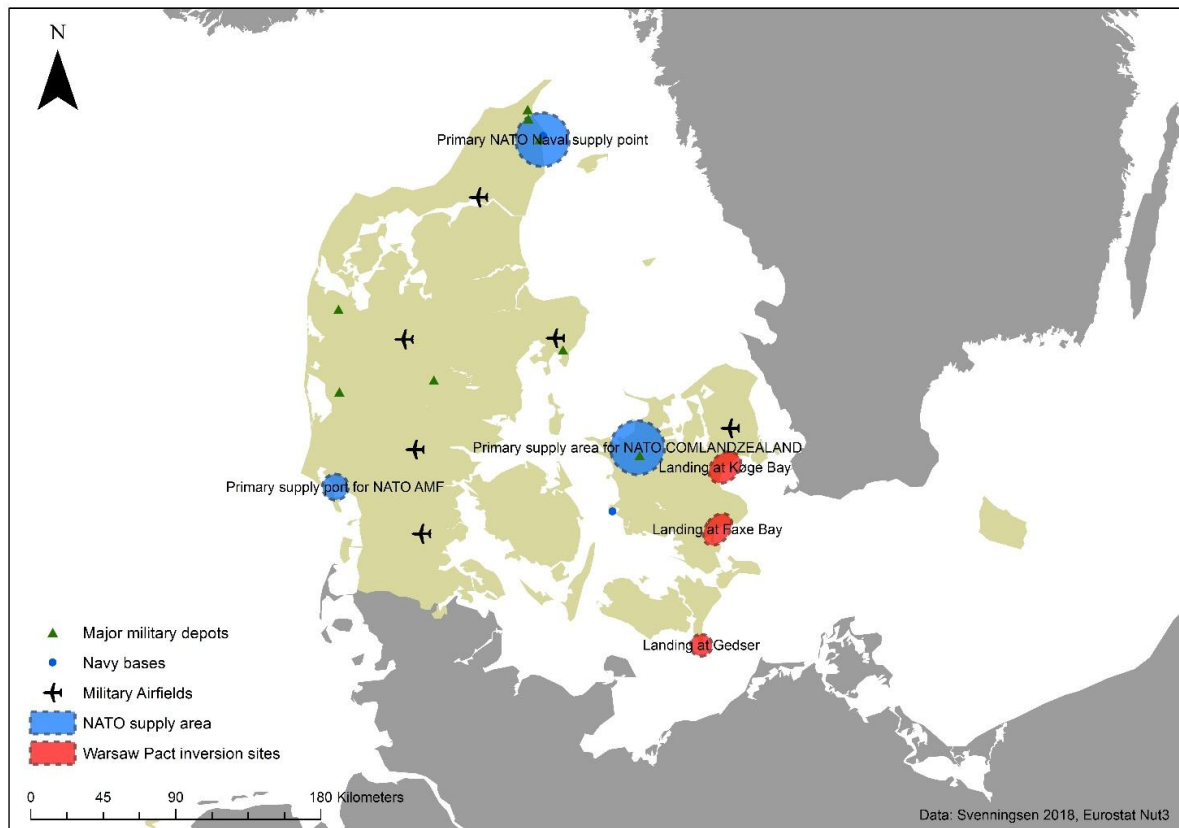


Figure 1: An overview of important military-operational areas in Denmark during the Cold War. Primary supply and base facilities for NATO forces is indicated by blue and sites for Soviet amphibious assaults on Zealand are marked with red.

### *Digital datasets for comparison*

#### *Maps*

Several datasets were included for the analysis of the content and source of information in the Soviet military maps. An obvious source is those Danish historical topographical maps that are contemporary to the Soviet maps, as well as the maps stated as sources on the Soviet maps. These maps are generally available in digital form from the Danish Agency for Data Supply and Efficiency, in most cases as georeferenced raster maps.

#### *Aerial imagery*

Historical aerial imagery has the potential to evaluate other sources of information used as basis for the Soviet maps and can also serve to estimate the temporal provenance of the information. A vast collection of aerial photography covering Denmark is accessible through the aerial imagery portal of the Danish Royal Library, which holds more than 1 million oblique and vertical aerial photographs recorded between the 1930s and 2010. The portal utilizes a crowdsourcing approach to the geo-locating of aerial photographs by requesting library users to assign coordinates to photos covering their local area. Although no quality assessment has been done on the accuracy of this method of geo-location, the portal makes it easy to locate and retrieve relevant aerial imagery

through the webpage or the API service of the Royal Danish Library. At the time of writing (February 2018) more than 85% of the published images have been assigned coordinates. Thus, the portal offers a dataset with a unique possibility for detailed information about changes on ground with a high temporal and spatial resolution (Svenningsen et al. 2015). This allows us to trace the time of time of geographical changes and compare it with information included in the Soviet maps.

#### *Accuracy assessment*

We propose a four-sided framework for assessing the potential sources to the information in the Soviet Military maps: positional accuracy, geometric accuracy, thematic/information accuracy and the degree of spatial-temporal accuracy or topicality if information. In this paper we have assessed the positional, geometrical and thematic accuracy visually. The maps have been graded on a scale from high to low based on our estimation of their accuracy.

- **Positional accuracy** is the degree to which represented features are accurately situated (value: unknown, low, medium or high).
- **Geometrical accuracy** is the degree to which the geometrical shape and extent of the feature is represented accurately (value: unknown, low, medium or high).
- **Thematic accuracy** is the degree to which the function of the feature/object (whether military, governmental or industrial etc.) is represented accurately (value: unknown, low, medium or high).
- **Spatial-temporal accuracy** is the degree to which information on the map matches the geospatial reality at time of production. In other words, whether its content is up-to-date (value: unknown, obsolete and updated).

#### *Source of information*

The results from the accuracy analysis can be used to identify the potential source of information in the Soviet maps. On most Soviet maps data sources have been listed on the map sheet with a reference to the scale of the source map, which makes it possible to identify the particular Danish map series from which the information was extracted. However, this information is often supplemented statement for additional information included later on; “с использованием материалов на” meaning “using materials from”, which is more ambiguous. It may be related to the use of aerial imagery, ground surveys or register data such as telephone books. According to Davies and Kent, a close examination of features on the Soviet maps can reveal much information about the potential sources (Davies and Kent 2017). Based on the extensive repositories of historical geographical information, such as historical maps and aerial imagery, we have carried out the following procedure to identify data sources using GIS overlay techniques.

1. Comparison of the positional, geometrical and informational accuracy of map features on the Soviet and Danish map listed as map source in the Soviet map.
2. Identification of differences and similarities in accuracy and selection of specific features which seem to differ compared to the stated source data.
3. Comparison between the selected features and contemporary historical vertical and oblique aerial photographs.
4. Further investigation of anomalies not explainable by the information retrievable from maps or aerial photographs.

## Analysis

### *The Soviet city plan of Copenhagen*

Our first analysis relates to a 1:25.000 Soviet city plan of the Danish capital of Copenhagen I-33-1,2,13,14, printed across two sheets in 1985. The map was compiled in 1972 and revised in 1982. It includes a descriptive text with basic background information, in Russian “Spravka”, and a list of objects listing 291 objects, although only 287 have currently been identified on the map sheet. The objects are represented on the in three different colors, each representing different categories of features (Black for industrial objects, purple for government and administrative objects and green for military and communications objects). The respective counts for the two sheets from Copenhagen are; Industry (195), Military (42) and Government (50), for an overview see figure 2. Military objects were key information for the Soviet military, thus we can expect a high degree of thematic and geometrical for these features. We therefore chose the military objects to test our approach of accuracy assessment. All military objects were digitized as point data based on the georeferenced city plan and analysis of the positional and geometrical accuracy was conducted based on Danish historical topographical maps and aerial imagery. The analysis of thematic accuracy and the quality of information was based on the information given in the object list compared to reference literature.

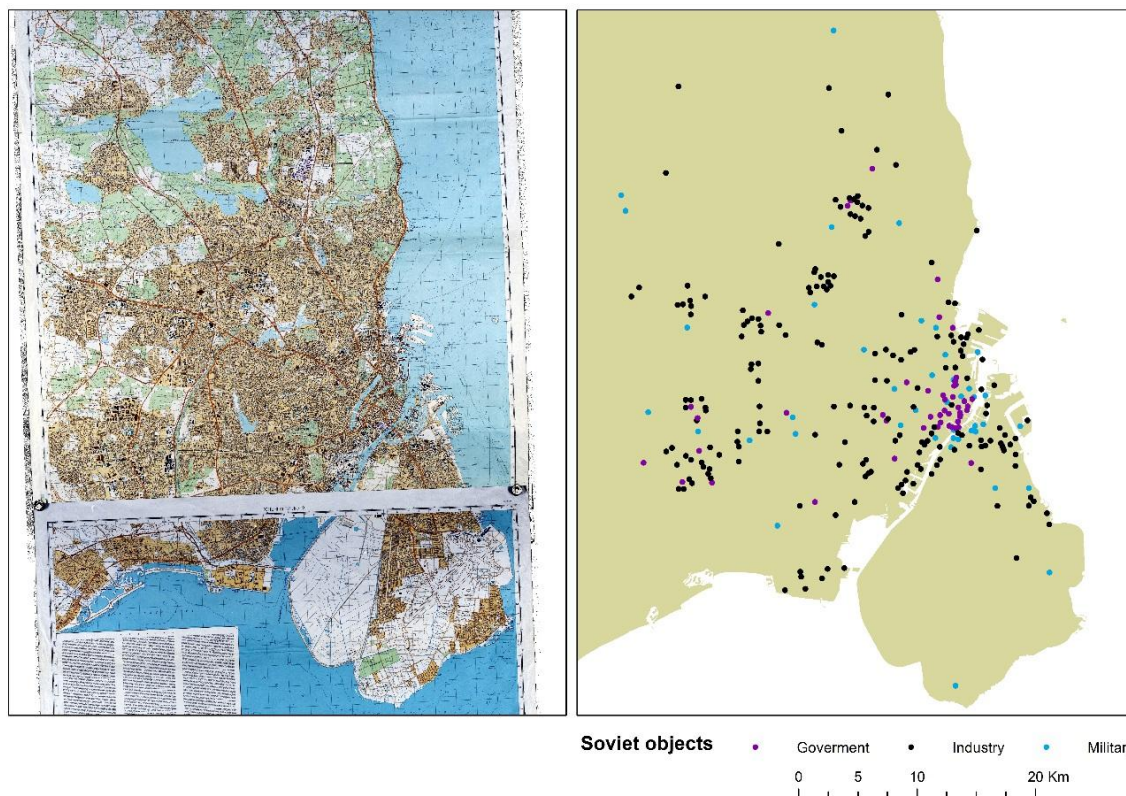


Figure 2: The distribution and type of objects extracted from the two sheets of the 1:25.000 city plan of Copenhagen. A total of 291 objects are listed on the map sheets, but only 286 have so far been located on the map itself.

In table 1. a summary of results from assessments of positional and geometrical accuracy. It indicates a generally high positional accuracy for the location of the military objects. However,

the geometrical accuracy of the object is significantly lower, as only seven objects have been assessed with the score “high”, comparing the geometry to concurrent Danish maps and aerial imagery. An overview of the thematic accuracy and quality of information on the objects is listed in table 2. Although 50% of the objects have been assessed to have a high thematic accuracy, this is somewhat challenged by the fact that several of the objects are presented thematically correct but with outdated geometry.

		Positional accuracy				Total
		High	Medium	Low	Unknown	
Geometric accuracy	High	7				7
	Medium	19	3		1	23
	Low	5	2	1	1	9
	Uknown	2			1	3
	Total	33	5	1	3	42

Table 1: Geometric and positional accuracy of military objects in Copenhagen

		Information quality			
		Correct	Obsolete	unknown	Total
Thematic accuracy	High	12	7	3	22
	Medium	2	2	1	5
	Low	1	4		5
	Uknown			10	10
	Total	15	13	14	42

Table 2: Thematic accuracy and quality of information of military objects in Copenhagen.

An illustrative case, of the figures in the tables is object 187, Svanemøllen Barracks, see figure 3. In this case the geometrical precision is generally mediocre (score=low). Not only is the geometry outdated, but some buildings in the residential area in the northeastern part of the map are missing. When it comes to accurately locating and delineating the feature, the map contains a major flaw. The majority part of the military facility is not presented with the appropriate signature (blue), and as such it has been assigned a low score of positional accuracy (score=low). However, by recognizing the areas function as military, it has achieved a high score of thematic accuracy (score=high). The spatial-temporal accuracy of the information is low (score=Obsolete), as the object has not been updated with new information. The part of the facility presented in the accurate signature had been abandoned at the time the map was printed. Strangely, the new railway line which ran through the abandoned buildings is depicted accurately.

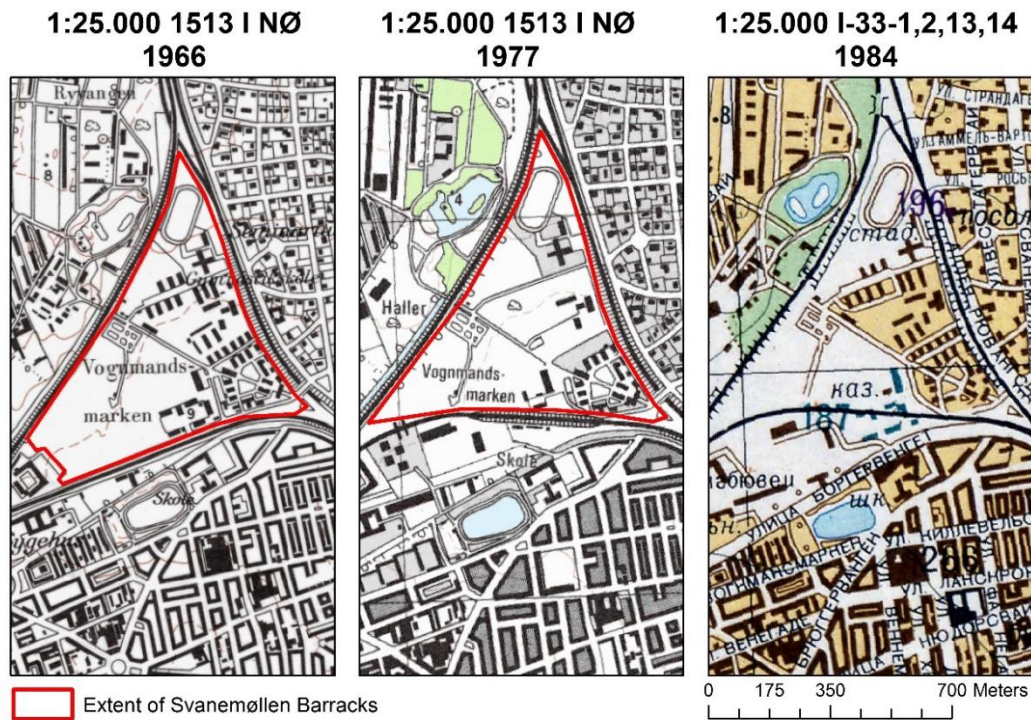


Figure 3: An extract from the Soviet city plan I-33-1,2,13,14 from 1984, showing object 187 Svanemøllen Barracks and two editions of the Danish 1:25.000 map sheet 1513 I NØ from 1966 and 1977. The Red line indicates the extent of the Svanemøllen Barracks in 1966 and 1977.

*Accuracy and source of information in large-scaled topographic maps*

*Faxe Bay*

Faxe bay was one of the most likely places for an amphibious Warsaw Pact invasion of Zealand. As such, it is an interesting area for a case study of the Soviet maps. The following section presents the results of our preliminary analysis of the map of the area. We focused on map sheet I-33-25-A in 1:50.000 printed in 1988, based on presumable maps in 1:20.000 from 1941-1945 and later revised with information dated to 1984. We suppose the maps in 1:20.000 refer to Danish topographic maps in that scale surveyed in 1940 and printed in 1944. This is a surprising choice of source by the Soviets, as a new Danish topographic map in 1:25.000 covering this area was published in 1973. Figure 4 presents a section of the Soviet map as well as the exact same area on a Danish topographic map in 1:50.000 from 1977 and an aerial photograph recorded by the UK RAF in 1982. Comparing the two maps, large discrepancies between the shape of the forest between the Soviet and Danish maps. The aerial photograph from 1982 gives a potential explanation, as large parts of forest was cut down in the period in between. However, the norm in specifications of Danish topographic maps was to indicate the area as forest if the area was replanted. This suggests that remote-sensed sources were used to update the map in 1984 and that the Danish map in same scale was not used.

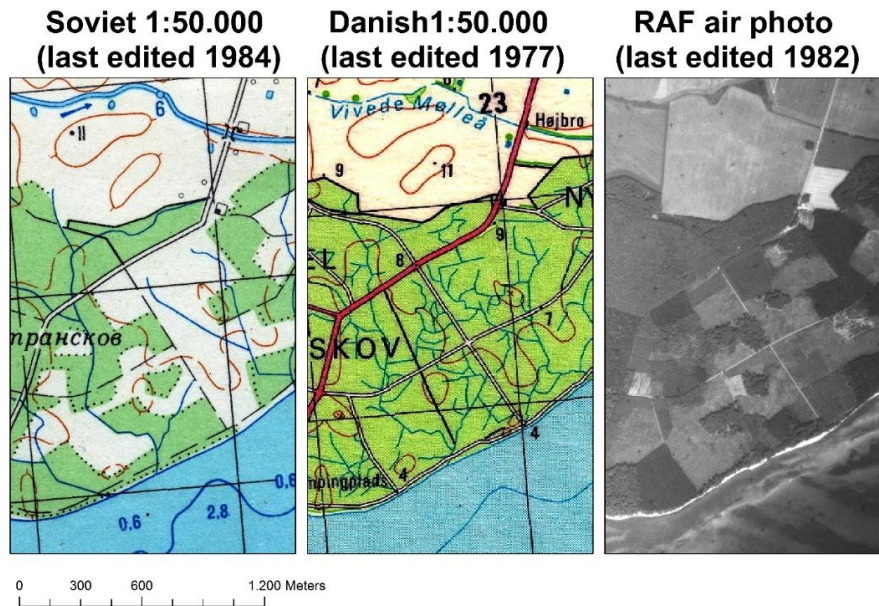


Figure 4: The Soviet 1:50.000 sheet I-33-25-A, compared with a Danish 1:50.000 sheet 1512 I based on data from 1975 and printed in 1977 and UK RAF aerial photograph recorded in 1982.

However, examining another area a little further to the West (see figure 5) around the village of Kissendrup seems to indicate that other information than aerial imagery was used. The Soviet map is marked with the sign for an airstrip just south of Kissendrup (red circle 1 on figure 5). This is likely correct, as the Danish map also show the presence of an airstrip, however situated approximately 500 meters further towards northeast (red circle 2 in figure 5). The airstrip is also visible on the RAF air photo from 1982 and there is certainly no airstrip in the area there the Soviet maps place the airstrip, as fields can be seen located across the area. This is an indication that the information on the airstrip was not based on remoted-sensed data. This serves as yet another indication that other sources than maps and aerial imagery have been employed.

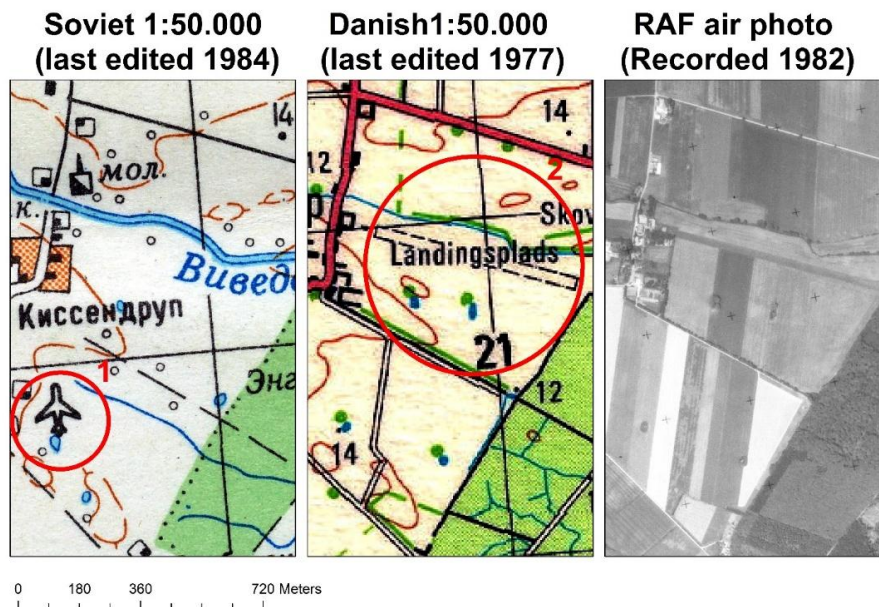


Figure 5: The Soviet 1:50.000 sheet I-33-25-A, a Danish 1:50.000 sheet 1512 I based on data from 1975 and printed in 1977, and an UK RAF 1:25.000 aerial photograph recorded in 1982.

Although the Soviet map seems to have been updated with new information since 1940s, some of the landscape features seem to have been retained throughout the period. Figure 6 shows the Soviet map together with the supposed original Danish source and the aerial photograph from 1982. Just north of the stream, the Soviet map is marked with the symbol for a chimney (red circle 1 on figure 6). Contemporary Danish map do not include any information about chimneys nor is it recognizable on the 1:25.000 RAF aerial photograph, and it is unlikely the Soviet mapmakers had access to aerial imagery with a higher resolution, as they were not able to precisely locate the airstrip. However, utilizing the vast collection of aerial imagery from the Royal Library, on a photo from 1988 the presence of a chimney is clearly visible on the old dairy building (figure 7). One possibility is that the Soviet mapmakers used information about the dairy from the 1944 1:20.000 map, and concluded that a dairy included a chimney, as the Danish map labels the buildings with “Mejeri” which is Danish for dairy (red circle 2 on figure 6). In another example, the Soviet map contains the label “шк”, school (red circle 3 on figure 6), in the same spot where the Danish map from 1940 has the label “Skole”, *school* (red circle 4 on figure 6). This is a clear indication that the Soviet features are based on the Danish map from 1940s, which in turn means they were obsolete at the time of printing.

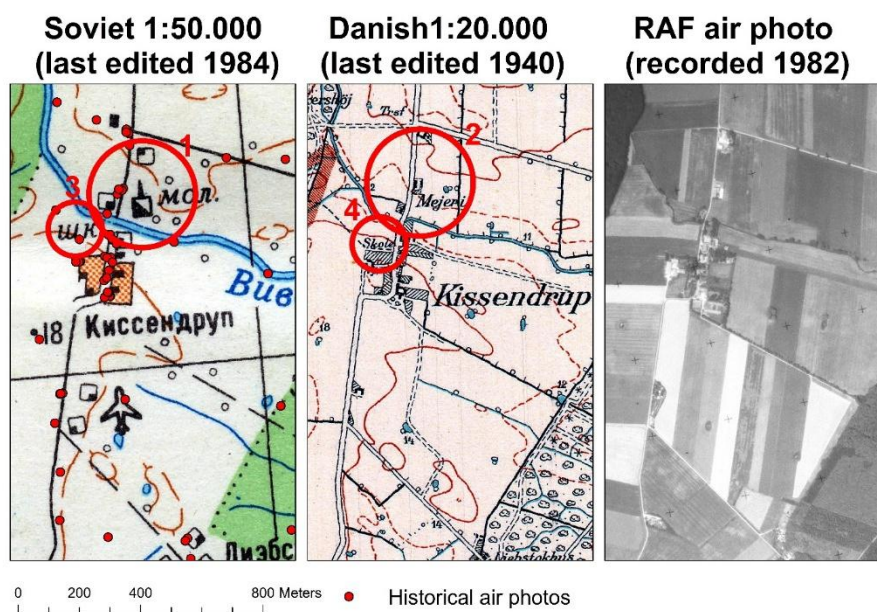


Figure 6: Soviet 1:50.000 sheet I-33-25-A, Danish 1:20.000 topographic map surveyed in 1940, printed in 1944 and a UK RAF vertical aerial photo in 1:25.000 recorded in 1982.



Figure 7: An aerial photograph of Kissendrup Dairy recorded in 1988 by Ariel Luftfoto. The photo clearly show the presence of a chimney in 1988.<sup>2</sup>

### *Concealed Danish military infrastructure in Soviet map*

The main supply area for the Danish forces on Zealand during the Cold war was located in northwestern Zealand around the town of Jyderup. The area is covered by the Soviet 1:50.000, sheet I-32-11-G, printed in 1985 and based on a map source in 1:25.000 dated 1971-1972, supplemented with information in 1984. Several ammunition and equipment storage facilities for the Danish Army were located in the area. One of the major ammunition depots was located by Tornved Forest. It was a standard policy by the Danish Geodetic Institute to hide sites of military importance on unclassified topographic maps during the Cold War (Stenak 2013). This is also the case with the ammunition depot in Tornved Forest, where only the road network within the forest is represented on the Danish map. On the Soviet map, some of the ammunition bunkers from the depot are indicated as buildings. This indicates the use of aerial imagery sources for the information on the Soviet Maps, which is supported by the fact that the bunkers are clearly visible on the 1:25.000 aerial photograph from 1985. On the Soviet map, the forest is marked with the symbol for mixed forest, which is difficult to assess based on the aerial photograph. However, the source of that bit of information could be the Danish 1:25.000 maps, as they make the distinction between coniferous and deciduous forest types. Oddly, the Soviet map contains the bunkers, but marks the area as forest, even though it seems cut down on the aerial photograph from 1985. This is a different situation than the example from Faxe bay, where it is likely that forest geometry was based on aerial photographs. A possible explanation could be that forest was cleared after 1984 or that they relied on the relatively updated information in the 1:25.000 map from 1970 which indicates the forest type: light green for deciduous forest and dark green for coniferous forest.

<sup>2</sup> [http://kb-images.kb.dk/DAMJP2/DAM/LuftfotoOM/0000/839/438/A088238\\_017/full/full/0/native.jpg](http://kb-images.kb.dk/DAMJP2/DAM/LuftfotoOM/0000/839/438/A088238_017/full/full/0/native.jpg)

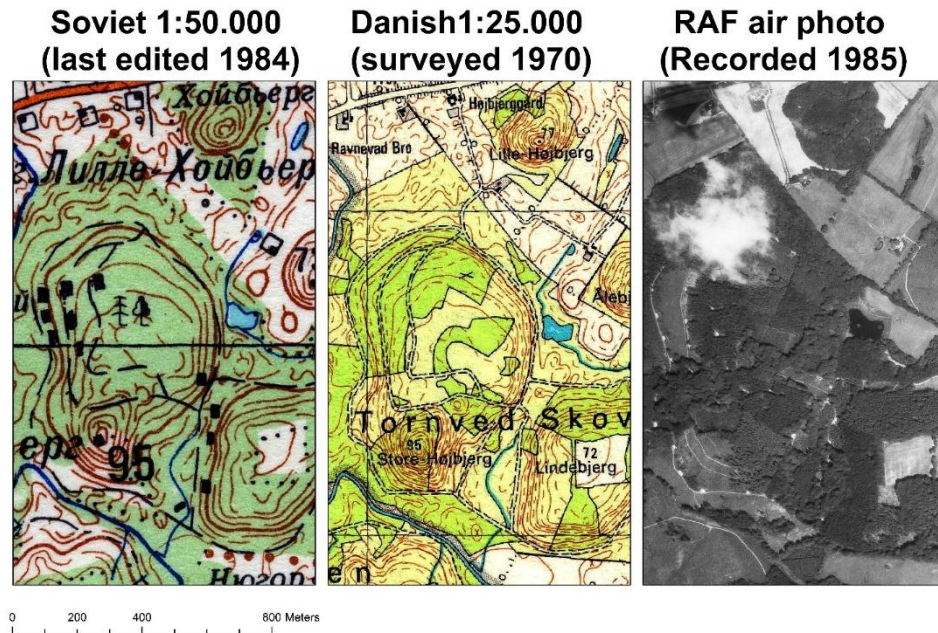


Figure 8: An extract from the Soviet map sheet I-32-11-G in 1:50.000, a Danish 1:25.000, sheet 1413 I SV from 1970 and printed in 1974 and a vertical aerial photograph from UK RAF recorded in 1985. Munition bunkers are clearly shown on the air photo and is also represented on the Soviet map, but is omitted on the Danish map.

### Discussion

The results of our initial analysis of a selection of Soviet topographical maps and a city plan reveals relatively large differences in positional, geometrical and thematic accuracy as well as the quality of information. Data repositories, with a comprehensive collection of digitized historical maps and aerial imagery, has been a key source for comparison of the Soviet maps with concurrent Danish sources. As illustrated in the cases from Faxe and Jyderup, detailed comparison with such data reveals much information about the accuracy of the Soviet maps and the array of data sources utilized by the Soviet mapmakers. The examples generally indicate a discrepancy between the geometrical accuracy of the Soviet maps and the concurrent Danish maps, suggesting that revisions were based on aerial imagery. The results from the analysis of the accuracy of military objects on the city plan of Copenhagen indicate that an assessment of the different kinds of accuracy is a promising approach to assess the general quality of large-scale Soviet maps. However, the process of mapping and comparing features is eased for the city plans by the specification of its objects. This is not the case with the large-scale topographical maps as they do not offer such designation of important features. These maps are more demanding due to the sheer amount of information on each map sheet and thus the selection of cases requires that an effort is made. Our solution was to focus on known key military areas such as Faxe Bay and Jyderup, which we suppose was of importance for the Soviet military. However, these areas should be supplemented by examination of areas with no obvious military relevance. An issue related to the assessment of the geometrical accuracy is the geo-referencing of the Soviet maps for comparison with other sources. Here, some of our results suggest that more emphasis on the projection of the Soviet maps would be beneficial, as errors met in the process of geo-referencing due to this issue might overstate the positional inaccuracy in Soviet topographic maps. So far, our approach has been based on visual assessment of the positional and geometrical accuracy and thus it is somewhat biased. Therefore, we see a need to develop standardized procedures for using GIS to

measure difference in positional and geometrical accuracy. Positional accuracy could be measured as offset in meters and geometrical accuracy could be measured as difference in area between shape of the object and reference data in percent. However, this needs to be thoroughly tested also in relation to potential errors from projection differences and representational practices on the Soviet maps.

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