DEVELOPMENT OF AERIAL PHOTOGRAMMETRIC RECORDINGS AND PRODUCTION OF DIGITAL ORTHOPHOTO MAPS IN THE REPUBLIC OF CROATIA

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ABSTRACT:
Development of aerial photogrammetric recordings for the whole territory of the Republic of Croatia and an overview of photomaterials that have been used for topographic survey and stored in the State Geodetic Administration archive are discussed in this paper. Since digital orthophoto maps at the scale 1:5000 have been produced recently, the manner of their production following the Book of Ordinances of Topographic Survey and State Map Production Manner with overview of accomplished works as well as digital orthophoto maps production plan until the year 2005 are explained. Available form and quality of the mentioned products are given here too.

1. INTRODUCTION

The first aerial photogrammetric recordings in Croatia date from the years 1929 and 1930 (Donassy, 1984), when the first aerial photogrammetric recording ordered by the «Government of the free and royal capital Zagreb» for the needs of general regulation map producing was carried out. Recording was accomplished with an unknown camera, and records were made in format 13x18 cm. Two photomaps at the approximate scale 1:10000 worked out from those records and some reproduction-slanting records from the mentioned recording with written documentation are kept in Museum of Zagreb city.

From those early beginnings of aerial recordings until now recordings in different scales and for different purposes have been carried out with continuity. Aerial recordings have always been used for multipurpose aims, but records have been used as main source for production of maps at different scales, photosketches, photomosaics and orthophoto maps.

Development of photogrammetry as a branch of geodesy has been intensive since the 40’s of the past century (in 1947 Sub-Department for Photogrammetry on the Geodetic Department of Technical Faculty in Zagreb was founded). Thanks to its experts (professor Franjo Braum, professor Vjekoslav Donassy, professor Teodor Fiedler, Plesko Jonatan etc.) Republic of Croatia has always followed and accepted all new technological achievements in domain of photogrammetry.

Development of aerial photogrammetric recordings can be divided into three phases: the first phase in the Yugoslavian Kingdom, where Croatia did not have possibility of its own development because of power centralisation in Belgrade, then the period after the Second World War till 1990 and the third period after becoming independent (1990) until today. Development of aerial photogrammetric recordings from above mentioned three periods and production of digital orthophoto maps in the Republic of Croatia following the Book of Ordinances of Topographic Survey and State Map Production Manner will be presented in this paper.

2. AERIAL PHOTOGRAMMETRIC RECORDINGS IN THE REPUBLIC OF CROATIA UNTIL THE YEAR 1990

In the period from 1956 to 1990 aerial recordings were carried out mainly for necessity of at that time called Basic State Map at the scale 1:5000 production, nowadays called Croatian Basic Map at the scale 1:5000. There were different recording scales (from 1:4000 to 1:17400). Recordings were accomplished by two institutions, Military Geographic Institute in Belgrade and Geodetic Institute in Ljubljana. The most part of aerial photomaterial is kept in the archive of the State Geodetic Administration. Photogrammetric recordings for the period between 1956 and 1990 are shown in figure 1.

The smaller part of photomaterial was recorded on glass-plates and the rest of it on the films. Since it is a case of priceless historical worth for the Republic of Croatia, State Geodetic Administration is converting all tentatively old photomaterials into raster format with precise photogrammetric scanner PhotoScan TD from Intergraph (Landek and Kaurić, 1997).
Concerning the war occurrences in Croatia between 1990 and 1996 a discontinuity in the aerial photogrammetric recordings occurred. The reason was that Croatia had not had its own aerial recording service before. However, in that period studies of justification of aerial recordings services founding were worked out what gave conclusion that for Croatia it is necessary to have at least one service for aerial recording. After gaining independence in 1993 the company Geofoto from Zagreb enlarged its geodetic works also on photogrammetric tasks. It carried out the first aerial photogrammetric recordings already in the spring 1994. Soon after that the second geodetic company Geodetic Institute in Osijek enlarged its activities on aerial photogrammetric recordings, so that there are two services for aerial recordings in Croatia at the moment. For recordings the planes Turbo Piper Aztec and Piper Navajo with integrated aerial photogrammetric cameras Wild–Leica RC20/30 and ZEISS RMK TOP 15 are used.

Cyclical photogrammetric survey started in 1996 specifically with recording of the west part of Istria from Umag to Pula (figure 2). After analysis of state needs, in 1997 it was concluded that it would be continued with recordings according to the priorities at that time. In May 1997 the north-west part of Croatia was recorded and at the same time aerial recording of the south-west part of Croatia started (figure 2). Since that year weather conditions were suitable, aerial recordings of Lika and towns Zadar, Šibenik and Split started too (figure 2). In 1999 and 2000 the whole middle and south part of Croatia were recorded, so that the whole territory of the Republic of Croatia was covered with cyclical aerial photogrammetric survey. It was the first cycle of aerial recording called “null-cyclical survey”.

Accepting the Book of Ordinances of Topographic Survey and State Map Production Manner published in the Official Gazette N.N. No. 55/2001 (further in this text “the Book of Ordinances”) real planned and aimed process of cyclical aerial photogrammetric survey started. In the article 8 of the Book of Ordinances it is given that cyclical aerial photogrammetric survey is made from the air at the scale not smaller than 1:20000 in the periods of 5 years.

“Null-cyclical survey” showed, what is later also included into the Book, that for the Republic of Croatia the best solution for the cyclical survey is the scale 1:20 000. Selection of region for the “null-cyclical survey” was conditioned by the war processes, which means that regions not occupied by the war were chosen. It was quite impossible to form symmetrical and harmonious blocks.

The second cycle of recordings was planned according to the Book of Ordinances so that each year about 20% of territory of the Republic of Croatia is recorded in order to get a recorded data as a main source for maps production.
LEGEND:

Figure 2.: Overview of cyclical aerial survey

LEGEND:

Figure 3.: Overview of new cyclical aerial survey blocks
(topographic maps at the scale 1:25000 and Croatian Basic Map at the scale 1:5000) not older than five years (according to the article 47 of the Book renewal of the maps is made in the period of 10 years). The territory of the cyclical survey is defined by the State Geodetic Administration manager in the annual state survey program. It is divided into five sectors, each of them with approximate area of 20% of the whole territory (figure 3).

In 2000 and 2001 the block Lika and towns Zadar, Šibenik and Split as well as West Slavonia were recorded, in 2002 and 2003 the block East Slavonia together with North-West Croatia with the wide area of town Bjelovar. This year cyclical survey of the block Zagreb with wider area and Istria jointly the wider area of town Delnice was contracted and should be carried out until beginning of April 2004 (figure 3).

It could be concluded that the territory of the Republic of Croatia was recorded in the “null-cyclical survey” between 1996-2000, and since 2000 about 60% of the whole territory has been contracted and recorded.

“Null-records” were used for different purposes, and mainly as primary source for production of topographic maps at the scale 1:25000 and digital orthophoto maps at the scale 1:5000. With the second cyclical survey since the year 2000 photomaterial for production of the same maps was provided, but with data not older than five years.

### 4. PHOTOMATERIAL SCANNED FROM THE CYCLICAL AERIAL SURVEY

In order to get scanned aerial records a precise Zeiss scanner with installed Intergraph PhotoScan software is used. Scanner has possibility to scan in different resolutions and memory needed for scanning depends on resolution as well as manner of recording (table 1). After scanning records are processes with Photoshop software.

In 2000 methodical storing of scanned records on CD-s started. Records were stored in needed resolutions in *.tiff format independently on orders. However, because of very sizeable quantity of memory necessary for records storing in *.tiff format, a need for records compressing in *.jpg format turned up. The archive of scanned records includes nowadays about 330 CD-s with approximate 8700 scanned records in different resolutions and about 1200 of them are stored on magnetic tapes.

Since 2002 films from cyclical aerial survey have been scanned systematically with a resolution of 21 μm, mostly for needs of digital ortho photo maps production and stored on magnetic tapes in *.tiff format (figure 4). Software used for image processing allows mathematical “corruption” of scanned records, what means that it is possible to have lower resolution from a better one.

<table>
<thead>
<tr>
<th>RESOLUTION (dpi)</th>
<th>RESOLUTION (μm)</th>
<th>MEMORY needed for a white/black record (23x23 cm) and recording scale 1:20 000</th>
<th>MEMORY needed for a colour record (23x23 cm) and recording scale 1:20 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>3630</td>
<td>7</td>
<td>1100 MB</td>
<td>3200 MB</td>
</tr>
<tr>
<td>1814</td>
<td>14</td>
<td>280 MB</td>
<td>800 MB</td>
</tr>
<tr>
<td>1210</td>
<td>21</td>
<td>127 MB</td>
<td>380 MB</td>
</tr>
<tr>
<td>907</td>
<td>28</td>
<td>72 MB</td>
<td>217 MB</td>
</tr>
<tr>
<td>454</td>
<td>56</td>
<td>18 MB</td>
<td>54 MB</td>
</tr>
<tr>
<td>227</td>
<td>112</td>
<td>5 MB</td>
<td>15 MB</td>
</tr>
<tr>
<td>113</td>
<td>224</td>
<td>2 MB</td>
<td>5 MB</td>
</tr>
</tbody>
</table>

Table 1.: Review of scanning resolution and necessary memory

A need for scanning in better resolutions (14 μm) appears trough developing software and raster processing technology, what considerably seeks after longer time necessary for scanning and image processing as well as more memory for data storing.

There are different groups of scanned records users:
- geodetic companies for digital ortho photo maps production according to the contracts with State Geodetic Administration (mostly used resolution 21 μm, and lately 14 μm),
- companies for production of topographic maps (using scanned records as auxiliary photosketches, mostly used resolution 56 μm),
- town-planning companies for producing of towns and municipalities regional plans (mostly used resolution 56 μm, and lately 28 μm),
- archaeologists for finding of possible archaeological locations before starting work (mostly used resolution 14 μm), and
- physical persons for different private needs.
5. PRODUCTION OF DIGITAL ORTOPHOTO MAPS

In the period of intensive construction from 1980 to 1990, especially during and after recent war, regions of Croatia have been significantly changed. Building and infrastructure destructions, changes of inhabitants structure, destruction of natural and economical resources, no development and mine pollution problem of different regions require integrated updating and production of new data bases (in digital form) for creation of geoinformation system.

Considering the needs and the costs of topographic maps production, as well as time needed for their production, State Geodetic Administration came to a conclusion that digital orthophoto maps could give enough satisfactory solution for wide field of extant problems.

The first contract was signed in the year 1994 (Jastrebarsko i Gorica) and the first 18 sheets were finished in 1995. Till 2001 digital orthophoto maps were produced as supplement product to the Croatian Basic Map at the scale 1:5000.

In July 2001 the Program of the State Survey and Real Estate Cadastre for the period from 2001 till 2005 was delivered and published in Official Gazette N.N. No. 64/2001. Through the program establishment of multipurpose spatial information system for the purpose of space management carried out by state authorities and public enterprises (Subprogram C) is foreseen and encompasses production of 5000 sheets of digital orthophoto maps 1:5000 (DOP) which corresponds to the half of the Croatian territory. A new strategy was accepted. Since that time production of orthophoto maps at the scale 1:5000 has been made from the cyclical photogrammetric survey records independently to the Croatian Basic Map production and according to the interests of State Geodetic Administration and other coinvestors.

Namely, State Geodetic Administration is responsible for production of all official cartographic and geodetic bases for civil purposes in the state, but there are also local authorities as well as some public institutions interested in their production. Considering that fact in the most cases of digital orthophoto maps production State Geodetic Administration concludes an agreement about its production with mentioned parties. According to such agreements State Geodetic Administration becomes owner of digital orthophoto maps and other parties get usage right.
In November 2001 State Geodetic Administration provided Instructions for production of digital orthophoto maps at the scale 1:5000 and since that time all sheets have been produced according to the Instructions and have been passing quality control process provided by the Croatian Geodetic Institute. Digital orthophoto maps are available in digital and analogue form.

In the year 2001 the mine-polluted area of Croatia covered 2326 sheets of Croatian Basic Map 1:5000. Considering not updated maps, at the end of 2001 CROatian Mine Action Centre (CROMAC) and State Geodetic Administration concluded an agreement about production of digital orthophoto maps. 1250 sheets were contracted in 2001, specifically 750 by State Geodetic Administration and 500 by Croatian Mine Action Centre (figure 5). This year (2003) Croatian Mine Action Centre is providing the further 250 sheets, donated by International Trust Fund for Demining and Mine Victims Assistance.

Table 2 gives review of digital orthophoto map production till today. All specified sheets, except 250 sheets which Croatian Mine Action Centre has contracted this year, have been already finished. For 484 sheets of them quality control process is finished (status May 2003).

Parallel with the Program of the State Survey and Real Estate Cadastre for the period from 2001 till 2005 production of sizeable number of digital orthophoto maps will be provided trough the World Bank “Real Property and Cadastre Project”.

<table>
<thead>
<tr>
<th>Period of DOP contracting</th>
<th>Number of DOP sheets as Supplement product to Croatian Basic Map</th>
<th>Number of DOP sheets Production by State Geodetic Administration and local authorities</th>
<th>Number of DOP sheets Production by Croatian Mine Action Centre</th>
<th>Total number of contracted DOP sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>till 2001</td>
<td>110</td>
<td></td>
<td>Adamantos</td>
<td>110</td>
</tr>
<tr>
<td>2001</td>
<td>852</td>
<td>500</td>
<td>1352</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>600</td>
<td>609</td>
<td>609</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2311</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Contracted digital orthophoto map sheets
6. CONCLUSION

Development and application of aerial photogrammetric records in the Republic of Croatia have their continuity from early beginning for use in different economical fields. From cross-section view it can be seen that first aerial photogrammetric records were used mostly for Basic State Map at the scale 1:5000 (nowadays Croatian Basic Map) production. Gaining independence Republic of Croatia started production of topographic maps at the scale 1:25000 and digital orthophoto maps on its own. Before decision about their production it was concluded that cyclical aerial survey should have been done at the scale 1:20 000. 

The Book of Ordinances of Topographic Survey and State Map Production Manner published in the Official Gazette N.N. No. 55/2001 gave the manner and procedure of topographic maps 1:25000 and digital orthophoto maps 1:5000 production. For production of both products aerial records recorded at the scale 1:20 000 are used. According to the specified review given in the paper it is noticeably that production goes in consistence with the Program of the State Survey and Real Estate Cadastre for the period from 2001 till 2005 (Official Gazette Narodne novine No. 64/2001, pages1948-1954, Zagreb 2001), so that Program plan fulfilment is expected, what means that topographic maps at the scale 1:25 000 will be produced for the territory of the Republic of Croatia (altogether 594 sheets), as well as 5000 sheets of digital orthophoto maps at the scale 1: 5 000 from totally 9821 sheets. In consideration of the fact that topographic database has been formed and that digital orthophoto maps are part of business information system, i.e. an integral part of the topographic base, the next steep is visualisation of the data from topographic base as base of geoinformation system, and in order to give fast information for needs of the whole economy in Croatia.

Literature:


