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EXPERIENCE WITH DIGITAL MAPPING AT LMV IN SWEDEN

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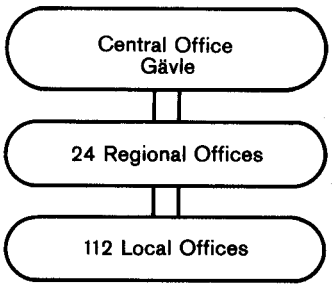
1. NATIONAL LAND SURVEY OF SWEDEN

The National Land Survey of Sweden (LMV in Swedish), is a government agency responsible to the Ministry of Housing and Physical Planning. The total staff of the Land Survey is of the order of 2,800. Since 1975 the Central office with about 900 employees has been located in Gävle. There are about 135 regional and local offices.



The Land Survey has three basic tasks:

* Cadastral survey and land consolidation
* Official mapping
* Services on a repayment basis

Cadastral survey, real estate formation and land consolidation are carried out by the local offices. The local organization also supplies a wide range of clients with various kinds of services on a repayment basis. These include, for example, the preparation of maps at the scales of 1:400 to 1:20,000 and the setting out and control of the location of buildings.

The central office has the responsibility for management, supervision and research and development within the field of land consolidation, land registration, land valuation and surveying and mapping. A major part of the production of the national map series, aerial photography and fundamental geodetic networks and much of the large-scale mapping is also carried out by the central office.

The Land Survey has the responsibility to produce the national map series at the scale of 1:10,000 and smaller scales for both civilian and military purposes. The responsibility for acquiring maps at larger scales, mainly 1:400-1:2,000, is vested in the communes.

2. ORTHO PHOTO PRODUCTION

2.1. Ortho photos

Photo maps have played an important role in Swedish map production since the middle 1930's when the production of the Economic Map at the scales of 1:10,000 and 1:20,000 started.

The Economic Map is based on a photo map background and also contains enhanced planimetric details such as buildings, roads, railways, power lines and hydrographic features. The map also shows the subdivision of the country into counties, judicial districts and communes. Parishes are also shown for land registration purposes and within this framework the division into separate properties is shown. Elevations are indicated by contours with a 5 metres interval.

At the time when the production of the Economic Map started the photo map was produced as so-called controlled mosaics. This method was used until 1966. During the years 1966-1978 two Gigas-Zeiss projectors were used for producing ortho photos. In 1978 a new computer-controlled ortho photo projector, a Wild Avioplan OR1, was introduced into regular production, see Figure 1.

The introduction of computer-controlled ortho photo production has meant an increase both in the geometrical quality of the ortho photos and productivity. Thus the number of ortho photo sheets produced has increased from about 300 to 850/year.

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Time period	Average production/year
1971-1975	300
1976-1980	600
1981-1985	850

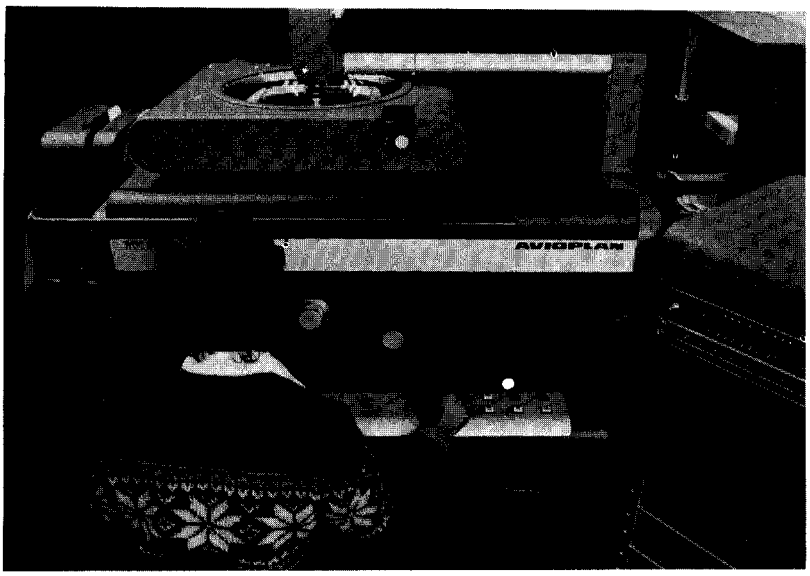

Fig. 1: Ortho photo projector Wild Avioplan

2.2 Elevation data

Using the Avioplan equipment it was necessary to have access to digital terrain elevation data with a high density. It was, of course, possible to acquire control information for each photo to be projected, but in order to take full advantage of the great flexibility inherent in the computer-controlled projection system it was considered rational to establish a high density terrain elevation data base to store this information in a suitable form.

Thus, in connection with the introduction of the Avioplan it was decided to start building up a country-wide elevation data base containing spot elevations in a regular grid with a grid interval of 50 metres. Today, ten years later, the elevation data base covers about 80% of the country and will be completed before 1990.

Data capture for the elevation data base has been made in three different ways:

* Photogrammetric measurements in aerial photos
* Digitizing existing contours
* Digitizing existing profile plates

Photogrammetric data acquisition can be performed in the profiling or contouring mode. Traditionally, profile measurements have been widely used in ortho photo production to capture elevation data from aerial photos. One great advantage with this method is the fact that the time needed for the data capture is relatively independent of the terrain elevations, which is not the case if data is acquired in the contouring mode. As a rule, profiling is much faster than contouring and consequently profiling is the method that has mainly been used by the Land Survey. For this purpose six Zeiss Jena Stereometrographs are used. These instruments have been equipped with digitizing equipment for output on magnetic cassette tapes, see Figure 2.

2.3 Future use of ortho photo maps

The elevation data base will be complete in 1990. The costs for producing ortho photos will, thereafter, not be affected by costs for producing elevation data. It will also be possible to deliver ortho photos very soon after aerial photography. Decreasing costs and delivery times will make it possible to start a programme to cover the country with ortho photos at different scales and time intervals such as, for example:

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Ortho photo scale	Time interval
1:50,000	3- 4 years
1:10,000	7-10 years

If such a programme can be implemented, ortho photos will play an even more significant role as a basis for producing the Swedish national map series. The availability of up-to-date ortho photos will then make it possible to considerably speed up map revision.

Another interesting aspect is the use of digital ortho photos. Digital ortho photos have been produced by scanning aerial photos in an IMTEC 4511 raster scanner, see Figure 3. After rectification, ortho photos were produced in a Scitex raster plotter. Producing digital ortho photos is not yet cheaper than producing ortho photos in the traditional way. However, the possibility of handling the picture together with other map data creates new, very interesting possibilities in map production.

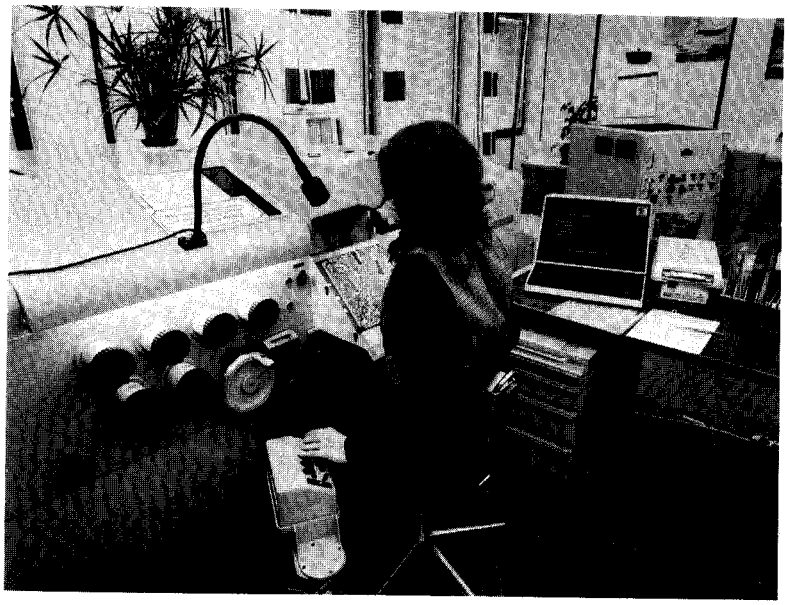

Fig. 2: Digital profiling using Zeiss Jena Stereometrograph

Fig. 3: Raster Scanner IMTEC 4511

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3. AERIAL TRIANGULATION

In-house developed software for aerial triangulation has been used since 1975. At that time, data capture was done using four Wild A7 instruments, and the first Wild A7 was equipped with linear encoders and inhouse developed software for data capture using a Tektronix 4052 desk top computer, see Figure 4. Within a few years all four Wild A7's were equipped in the same way.

Fig. 4: Digital mapping using Wild A7

The first analytical plotter, a Zeiss Planicomp C100, was installed in 1981, see Figure 5. Since then further two Planicomp instruments have been installed in Gävle and the Wild A7's have been connected to the HPcomputers of the Planicomps, and the Zeiss software for data capture is used. Currently, a very small part of measurements for aerial triangulation is made using Wild A7's.

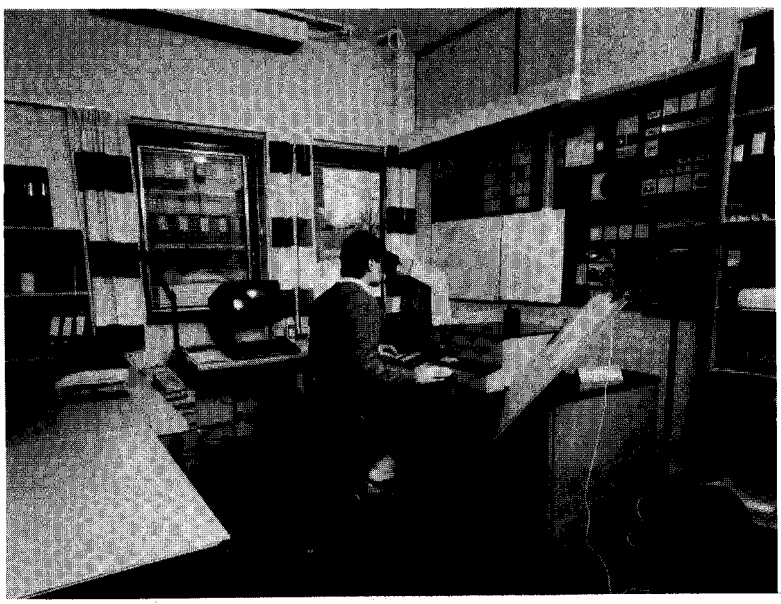

Fig. 5: Analytical plotter Zeiss Planicomp

At the present time the following equipment and software is used for aerial triangulation:

Equipment	Make	Number	Use
Planicomp	Zeiss	3	Data capture
A7	Wild	4	(Data capture)
PUG	Wild	1	Point marking
CPM	Kern	2	Point marking

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Software	Make	Use
BLOCK	In-house	Model triangulation
PAT-M	Ackermann	Model triangulation
PAT-MR	Ackermann	Model triangulation

The average production rate for aerial triangulation expressed as number of models per year are as follows:

Time interval	Number of models/year
1971-1975	2 100
1976-1980	2 300
1985	3 100

The introduction of analytical plotters for aerial triangulation has meant that it has been possible to increase production by about 50% using one instrument less than was used before for data capture.

4. PHOTOGRAMMETRIC MAP PRODUCTION

4.1 Urban maps

The Land Survey produces urban maps on a repayment basis. The scale of these maps ranges from 1:400 to 1:5,000. At the present time analogue photogrammetric instruments are still used for this kind of product. The instrument most commonly used is the Wild A8, but also Wild A10 and Zeiss Topocart instruments are used. The production of urban maps is located to Gävle and a number of regional offices:

Location	Number of instruments
Gävle	8
Malmö	4
Norrköping	6
Luleå	3
Göteborg	1
Umeå	2
In total:	26

Tests with computer-aided mapping were started in 1975 and phased into production in 1978. Most instruments are equipped as the Wild A7 shown in Figure 4. A few instruments, however, are equipped with IBM PC's.

Currently, almost all instruments for urban mapping are fitted for computer-aided mapping and about 90% of the production is done using digital methods.

4.2 Small scale maps

By small scale maps is here meant maps at the scales of 1:10,000 or less. This scale range in Sweden comprises the national map series

1:10,000 1:20,000	Economic Map
1:50,000 1:100,000	Topographic Map
1:250,000 1:500,000	General Map

Up to now photogrammetric map compilation has only been used for contouring in connection with the production of the national map series. Thus, the planimetric details of the Economic Map are derived by using ortho photos as a background for field work. The planimetric details of the Topographic Map are produced in a similar way by fair drawing of manuscripts after field work. As the Topographic Map is in a revision stage the manuscript is based on an old Topographic Map as a rule.

Lately, however, there has been a great interest in the use of photogrammetric instruments for mapping planimetric details. For this purpose a Zeiss Planicomp with the VIDEOMAP superimposition system has been used. So far limited tests have been done both for the Economic Map using the image scale of 1:60,000 and the Topographic Map using the image scales of 1:60,000 and 1:150,000. During this year a production test of about a hundred map sheets for the Economic Map will be started using a Planicomp fitted with VIDEOMAP.

5. USE OF DIGITAL MAP DATA IN SWEDEN

5.1. Urban maps

Experiences have shown that costs for producing urban maps by digital or conventional methods are about the same. The great advantage of using digital methods is not primarily lower costs but rather the fact that the user beside the conventional map also gets a new product, the digital map. However, up to now, not many users have been able to handle the digital map data, and consequently it has not been possible to make use of the inherent advantages of the digital map.

In Sweden there is a strong belief, however, that digital map data will be used on an increasing scale in the future, which has meant that the main part of photogrammetric urban mapping in Sweden is already done using digital methods.

At the present time there are about ten communes in Sweden that have bought and installed an IGS-system of their own. The IGS-systems used are as follows

* AutoKa
* Computervision
* Intergraph
* MARIT
* Siemens

In the systems mentioned above, all digital map data is stored in a data base. Most users, however, have computer systems where only the pointdetails are stored in a data base and which, as a consequence, only can handle digital map data to a limited extent.

The change from conventional maps to digital maps is by no means easy. The situation in Sweden today is that the communes that have IGS-systems of their own still use the old system with conventional maps parallel with the digital map. The time when digital maps will fully replace the conventional map handling is still to come and still for many years the two map systems will be used concurrently.

There are several reasons why the use of digital map data has not advanced as quickly as was predicted some ten years ago. Some of the reasons are

- Lack of complete software systems
- Software and hardware are too expensive
- The necessity of cooperation between different branches in the communes
- Training is time-consuming and expensive

One of the biggest problems, however, is the lack of digital data. The digital map cannot be fully used until digital data covering the whole commune is available. To achieve this goal it will take time and will be expensive. In Sweden it has, therefore, been discussed if the digital map should contain all the details shown in the conventional urban maps. It has also been proposed that efforts should be made to make use of the better accuracy of analytical plotters and the better image quality available today by increasing the flying height for aerial photography. Thus, this year such tests are being made by increasing the flying height from 800 meters to 1,500 meters.

5.2 Small scale maps

Digital methods have been used since many years in the production of the national map series. Data collection has mainly been done by manual digitizing of manuscripts. Raster scanning has only been used to a limited extent. Until now the digital content has been limited to the symbols, line elements and texts of these maps and drawing has been done using vector plotting and photo setting. During 1987 a Scitex and a Calcomp raster plotter have been installed and tests are in progress using raster plotting for producing different layers of the national map series.

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With few exceptions, the small scale digital data bases have been built up for producing a specific map with a second goal that these data bases could be useful for other purposes and other users. This has not been the case to the extent that was hoped. One reason is that the data bases do not cover the whole country but are in the progress of being established and are steered by the national mapping programme. A second reason is that the geometry of the map details very often is manipulated in order to suit the production of a specific map. Consequently this kind of data bases should be called cartographic data bases.

It has become increasingly clear that it is especially important that the data bases are country-covering, or at least as far as possible, before they really can be fully utilised. Examples of this kind of data base in Sweden are

* Elevation data
* Ortographic names
* Geographical Sweden data

These data bases are used not only by the Land Survey for mapping purposes, but also by a growing number of other users. Especially the Elevation Data Bank has been used in a lot of different applications as for example:

- Hill shading
- Geological Studies
- Radar visibility studies
- Radio communication studies

As a result of the experiences from the use of existing small scale data bases it is proposed that larger efforts should be made to build up general country-covering data bases, so called geographical data bases, rather than cartographic data bases.

One example of such a geographical data base is the Road Data Base. Building up the Road Data Base is run as a separate project in cooperation between the National Land Survey and the National Road Administration. The project was started in the end of 1986 and it is planned that data capture will be completed during 1989. The geometric information about the road net will be captured from aerial photos at the scale of 1:150,000 by using analytical plotters. Data capture comprises co-ordinates in x, y and z and the accuracy of the co-ordinates is specified to be of the order 2-3 meters in plan as well as height. The geometrical data will be stored and connected to already existing descriptive data for the road net.

In this first stage the project only covers the national road network. It is discussed, however, to extend the project to cover private roads as well.

6. FUTURE USE OF DIGITAL PHOTOGRAMMETRIC MAPPING

The demand for digital data covering large areas will no doubt increase considerably as more users will get an IGS-system of their own and as experience of handling digital data increases. This demand will certainly result in the need for creating country-covering geografical data bases covering specific themes like roads, hydrography, land use etc. In the large scale range there will also be a great demand for building up commune-covering data bases of good geometrical quality in order to make it possible to take advantage of the digital map.

One big question is what methods should be used to capture this huge volume of data in a relatively short time. It can be concluded that using analogue instruments for photogrammetric mapping will result in about the same cost level either conventional mapping or digital methods are used.

This cost level is probably too high to make photogrammetric data capture competitive with digitizing or scanning of already existing maps. It should be possible, however, to lower this cost level considerably by increasing the flying height for aerial photography to about the double. By making use of the better accuracy of analytical plotters and the better image quality offered by cameras with movement compensation and new films by increasing the flying height it should be possible to maintain a high quality of data capture at a much lesser cost. If this prediction comes true it would mean that, within a few years, analogue photogrammetric instruments will not be used any more.

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