

AERIAL PHOTOGRAPHY FROM VERY HIGH ALTITUDE IN SWEDEN

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Introduction

The Swedish national air photography programme has for a long time applied the standard flying altitudes of 4 600 and 9 200 m. Since wide angle lenses with 15 cm focal length have been used, the negatives have the scales of 1:30 000 or 1:60 000 respectively.

Already in the first part of the 1960's the Geographical Survey Office - now the Land Survey of Sweden (NLS) - carried out a number of tests using a superwide angle lens unit. An evaluation showed that the negative quality did not meet mapping requirements. However, in the early 1980's it became clear that aerial photography at a smaller scale would be useful in some applications. Then better superwide angle lenses had been developed. Thus a test programme was started in order to evaluate the possibilities to carry out and introduce superwide angle photography at an altitude of 13 200 m. The reason to choose the 13 200 m altitude is that this altitude gives the negative scale of 1:150 000 and is close to the highest possible altitude which can be reached by in Sweden available aircraft equipped for aerial photography. This paper gives a summary of the experiences gained from the test programme and from the realization of a new photography programme. Moreover examples and experiences of the use of this kind of photo material in different applications are given.

Test programme

The test programme was carried out in 1982 and 1983. The aim of the programme was to evaluate the possibilities to carry out superwide angle photography from very high altitude. With such photography it would be possible to cover very large areas with limited flying time. Another aim was to study the possibilities and limitations in using small scales photography in ortho photo production, for production and revision of topographic maps at the scales of 1:50 000 and 1:100 000 as well as to study other possible applications of such photo material.

The test photography missions were carried out using black and white panchromatic film and, to a limited extent, colour I/R film. The photo missions covered some ten areas in the south, middle and north of Sweden. In total about 1 000 pictures were exposed. Generally speaking the image quality was very good. In the test programme some problems were experienced due to icing on the glass camera window when flying at high altitudes with an outer temperature of around -50°C . This problem was solved by heating the camera window with hot air. No icing problems have existed in the photo missions carried out in later years.

In Sweden so far only aircraft of the Lear Jet 35 type is available for aerial photography at as high altitude as 13 200 m. A special door is used for photo missions and the camera is mounted in this door (see figure 1).



Figure 1. Aircraft of the Lear Jet 35 type used for aerial photography at 13 200 m. The plane is equipped with a special door housing the camera.

The initial test photography was carried out with a Wild RC10 camera equipped with an SAg II unit provided by Wild, Heerbrugg. As a result of the good results of the work carried out in 1982 and 1983 the Land Survey purchased an SAg II lens with a camera constant of 87.97 mm.

The use of small scale, superwide angle negative material for ortho photo production is dependent on both the software and the volume of steering information. To minimize the effect of terrain elevation the ortho photo must be exposed through the smallest possible slit. For standard production in the Wild Avioplan OR1 instrument at the Land Survey a 5 mm slit is used. Using superwide angle imagery the smallest available slit - 3 mm - should be used if height data of equivalent density is available and if highest geometric quality is demanded.

A practical problem arose as a result of the construction of the height data base system used by the Land Survey. To produce a 1:50 000 ortho photo for a standard 1:50 000 topo sheet, height information must be recalled from 49 separate data bases. When the software for the production of ortho photos was written at NLS the need for such large volumes of height information was not foreseen. Therefore, for the purpose of carrying out these tests, it was necessary to modify the software used to generate control information. Other practical problems may be related to available

space on disk storage units. Software modifications solved these problems.

The main reason to produce ortho photo maps at the 1:50 000 scale was to try this material in the production and revision of topographic maps. Thus it was found that in the revision of the 1:50 000 map series ortho photos constitute a very suitable base material. New roads and other planimetric details including even single houses could easily be detected. The good geometric quality very much facilitated the map up-dating. The 1:50 000 ortho photo maps were also tested in the production of the new topographic map at 1:100 000. Also in this context the ortho photos were found to be most useful.

As part of the experiments with superwide angle imagery a number of ortho photo maps were also produced for regional planning purposes. This part of the work was paid for by communes and regional planning associations. This indicated a real need for such material. Another indication in the same direction was that this map material was used in several cases to illustrate different planning activities.

Ortho photos at 1:50 000 completed with additional information such as administrative border lines and place names was also purchased by the military and the police as well as by forestry organisations and enterprises.

A new photography programme

The tests presented above showed that high quality aerial photographs could be obtained using superwide angle camera mounted in jet aircraft flying at high altitudes. The experiments also showed that this photo material could be used for a range of applications and that its use would result in rationalisation of the mapping process at the Land Survey. It was also obvious that there was a need for such material among a number of users outside the Land Survey organisation.

As one important result of the experiments reported in this paper, the new National Mapping Programme 1985-1995 includes provisions for a high altitude photography programme. Black and white photography will be taken using a superwide angle unit from an altitude of 13 200 m and covering the whole of Sweden. The complete programme will be repeated at 3-5 yearly intervals. This programme was started in 1984. Since then large areas have been covered within this programme and much experience has been gained from this work as well as from the use of this kind of photo material.

Film material

Colour IR/film was used to a very limited extent during the test period. Although good results were achieved with this film type it was decided to use only black and white film in the ordinary programme.

Most of the photography has been carried out using Kodak Panatomic X or Double X film material. The experience so far is that in

particular the Panatomic film is slightly too hard for Swedish weather conditions. The Agfa Gaevert Pan 50 and Pan 200 films have been tested at lower altitudes, especially 4 600 m. The results with the Pan 50 film are very good. For this reason we intend to make use of this film type also for the 13 200 m photography during the season to come.

In table 1 some basic production facts are given for the years 1984-87. As seen from these figures the average area covered each of the four years amounts to slightly more than 100 000 sqkms. The total area of Sweden amounts to some 440 000 sqkms. This means that about one quarter of the country has been photographed each year. This corresponds well with the idea to repeat the photography programme with a time interval of 3-5 years.

The average flight time per year is about 40 hours. The best result in terms of covered area per hour was achieved in 1987. One reason for this is certainly that the photography this year was carried out much earlier (May-June) than other years. This verifies that the weather conditions during the early part of the summer are most favourable for this kind of photography in terms of production rate. However, it is a problem to get access to Lear Jet aircraft during the most appropriate photography period, which occurs in May and June. During these months Lear Jet aircraft are much demanded for transportation of business men on the eve of the holiday season. This also means that the rent of aircraft is considerably higher during these months than during July and August. This is the reason why the cost per sqkm is relatively high for the 1987 photo season.

Table 1 Superwide angle photography from very high altitude during the years 1984-87
6 SEK = 1 US\$

Year	Covered area sqkm	Number of exposures	Flying time h	Covered area sqkm/h	Total costs SEK	Cost/sqkm SEK
1984	93 300	877	35	2 643	502 000	53.8
1985	82 000	821	33	2 522	691 300	84.3
1986	128 400	1 321	54	2 377	744 200	58.0
1987	113 100	1 198	36	3 159	867 400	76.7
Average	104 200	1 054	40	2 675	701 200	67.3

Use of small imagery

Small scale photo material can, generally speaking, be used in the same way as standard aerial photographic products: densification of control, digitizing and the production of ortho photos and line maps. Some examples of the use of small scale aerial photos are given here.

Photogrammetric digitizing

Small scale photography can, with advantage, be used for digitizing planimetric details in stereo plotters. For example, this

material is particularly suitable for digitizing such features as roads and railways. The position of welldefined details can be determined with a standard error of about ± 2 m in X, Y and Z. This means that the digital data can even be used for medium scale mapping up to scales of 1:10 000. In forested areas, details can be hidden by trees, but in tests so far carried out in southern and central Sweden it has been possible to digitize 100% of the public highway and railway network. Minor roads could not be fully digitized due to problems with interpretation: an 85% level seems, however, to be a reasonable estimate in wooded and forested areas. Regarding productivity, our experiences have shown that high digitizing speed can be maintained when working in stereo plotters. Stereo plotters are in fact generally better suited to digitizing than digitizing tables. Even in areas with a dense road network it has been possible to digitize the complete road net of a 50x50 cm 1:50 000 topographic map sheet in approximately 40 hours. This is much faster than with alternative methods.

The experiments with the use of small scales pictures of acquisition of digital road data have been carried out in a Planicomp analytical plotter equipped with a Videomap system. With this equipment the operator can view the digitized information superimposed on the aerial picture. This facility is certainly of great help to the operator and makes photogrammetric digital data capture to a very efficient method.

In Sweden the establishment of a national road data base has now been started. The work will be carried out by the Land Survey in close co-operation with the National Road Administration. Data capture will be carried out in analytical plotters. X, Y and Z-coordinates will be determined for road centre lines. In the first phase public roads and railroads will be captured. This work is planned to be completed by 1990. In a second phase all private roads will be included in the national road data base.

Ortho photo production

Superwide angle imagery at a negative scale of 1:150 000 is suitable for the production of ortho photo maps at the 1:50 000 scale. Access to reliable terrain elevation data is a prerequisite for ortho photo production. In Sweden, a dense terrain elevation data base is at present being established. Data capture began at the beginning of the 1980's and is planned to be completed by 1989. Terrain elevation data is stored in a 50x50 m grid.

The present situation in the production of the national high density elevation data base is that some 16 000 grids at the size of 5x5 sqkms have been stored in the data base. This means that well over 85% of the country or some 370 000 sqkms have been covered by DEMs.

Due to the good experiences of the use of ortho photos in production and revision of topographic maps the National Mapping Programme has been extended to include also production of ortho photo maps at the scale of 1:50 000. Thus during the last years

ortho photos have been produced to cover some 300 sheets of the 1:50 000 topographic map series.

Another example of the use of small scale aerial photos is in production of an overlay to the topographic map series giving details on control points for measuring activities within the defense forces. For this purpose x, y and z-coordinates have to be determined with maximum errors less than 8 m in x and y and less than 3 m in the z-coordinate for about one point per sqkm in the whole country. The geometrical quality demands are attained by block triangulation with the 1:150 000 photos. From an economic point of view this technique is by far superior to alternative geodetic or photogrammetric methods.