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Presented paper: Photogrammetry and Field Surveying at the National Swedish Road Administration

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Summary:

The use of photogrammetry and field surveing in highway design and construction at the National Swedish Road Administration is described. A special attention is given to a digital on-line stereo plotting system using a Wild A8/Aviotab and a desktop computer Hewlett-Packard 9825A. Field surveing and setting out methods are described, in particular an interactive total field station consisting of an AGA Geodimeter 700 interfaced with a solid state memory AGA Geodat 120 and with a two-way digital radio communication with a remote Hewlett-Pacard 9825A desktop computer.

PHOTOGRAMMETRY AND FIELD SURVEYING AT THE NATIONAL SWEDISH ROAD ADMINISTRATION

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1. Introduction

Photogrammetry and field surveying have been applied to highway design for more than twenty years at the National Swedish Road Administration (NSRA). Together with data processing and automatic plotting they are indispensable parts of the complete highway design system.

The basic principles for the use of photogrammetry and field surveying at NSRA have been described in a number of reports (e.g. Working Group Report IV/1 to the 13th ISP Congress in Helsinki 1976). Therefore this paper only contains a brief description of the present application of photogrammetry and field surveying to highway design and construction at NSRA. In addition special interest is given to a few developments during the last years.

2. Photogrammetry

2.1 Existing maps and aerial photography

In the first design stages especially route location, it is more important to get general and comprehensive information rather than detailed, accurate information about topography, geology and land use. Consequently topographic maps and aerial photographs in medium scales are the most common sources of topographic information.Official maps are therefore generally used in route location studies, either the Topographic Map (1:50 000) or the Economic Map (1:10 000). These maps are produced by the National Land Survey of Sweden (NLS). NLS also carries out aerial photography (photo scale 1:30 000) regularly according to a rephotography plan. The country is divided into regions and for most regions the photography is repeated every seventh year. These acrial photographs are of great importance in areas where the official maps are old.

Other existing topographic maps in larger scales (1:5 000, 1:2 000) are being used whenever possible. Such maps are often available from community planning offices and are being used for by-pass-road projects.

The major part of public road investments is today allocated to by-pass-roads and improvements of the existing road network. For by-pass-roads, maps are available through city planning offices and for the design of improvements topographic maps in the scale 1:1 000 or 1:2 000 are being produced without any prestudy in Blaplex Plotter.

The number of Balplex Plotters within NSRA has gradually decreased and is today eighteen instruments.

To-day the production of large scale road project maps is the main photogrammetric activity at NSRA. The working procedure of the photogrammetric map production will be described in this section.

The maps production has the following characteristics

- the maps are produced at one occasion (in late preliminary design stage) for one purpose (design of roads and highways in rural areas) and at one scale (1:2 000).

- the maps have a limited time of interest (mainly during design stage). No systematic up-dating is made

- the maps are inked at plotting stage in order to give reproducable map originals with as few production steps as possible

At present the following photogrammetric instruments are owned by the Roads Administration

1 Wild A10	with Ek8, linear xy-digitisers and rotary z-and by-digitisers
2 Wild A8	with LOGIK 5000, linear xy-digitisers and rotary z-and ω-digitisers
1 Wild A8	with Ek20, linear xy-digitisers, rotary z-and and rotary z-and ω-digitisers and Aviotab TA plotting table with PRI1 interface
1 Wild A8	with SAAB UE-211, rotary xyz-digitisers
1 Wild A8	

Numerical relative and absolute model orientation is being used regularly. Desk-top computers (Hewlett-Packard 9820, 9825) are used off-line or on-line to the stereoinstruments for adjustments of orientations and for adjustment of grid tests of the instruments.

Aerial triangulation (model triangulation) is being used to some extent to densify planimetric and elevation control. Certain requirements are given on the distribution of ground control in these cases. The adjustment result contains e.g. scale setting values for model formation at plotting stage.

2.2 Aerial photography

Aerial photography is generally required in the preliminary design stage in order to have an up-to-date photography over a specified project area.

Wide angle photography is used and the photo scale is normally 1:10 000. Due to the long and narrow shape of the project areas the photography consists of single strips in sequence after each other. Blocks of strips are not very common. Most photography is made on ordinary black and white film.

For numerical measurements of cross-sections, profiles etc. during final design and even at construction stage aerial photography is performed with a photo scale of 1:4 000 or 1:5 000.

The aerial photography is carried out by the National Land Survey upon order from NSRA.

2.3 Map production

The main application of photogrammetry in highway design is found within preliminary design and is based on the aerial photography in the photo scale 1:10 000.

For many years there has been a two-fold evaluation of photographs in preliminary design - determination of feasible routes and production of topographical project maps in the scale 1:2000.

The first evaluation was made in a Balplex Plotter. The work in this instrument was primarily a topographical study of various proposed alignments. Measurements of cross-section and profiles were made to compare different alignments. The benefit of using Balplex Plotter was that several alternative alignments could be studied and compared in a short time and thus a more "optimal" solution could be expected. At the same time the corridor that was left for further detailed studies became very narrow and the costly production of large scale topographical project maps could be held at a minimum.

The use of Balplex Plotters in Sweden has decreased during the last years due to many reasons. One is that official topographic maps in the scale 1:10 000 and 1:50 000 today cover the major part of Sweden, giving acceptable topographic information for selection of feasible routes. Another reason is that a lot of other factors apart from topography are of great importance for the selection of feasible routes.

Possible ways of improving the stereo plotting procedure have been discussed during the last years. The rapid development of computer-based interactive graphical systems for various purposes (e.g. digital map data bases) had to be considered.

With the characteristics of the map production at NSRA (given above) as a background we came to the conclusion that a computer supported stereo-plotting system should be tried rather than a system with a digital map data base and on off-line plotter. As we have Wild instruments it was natural to try Aviotab/PRI1 in the first place.

Since aug -79 a digital on-line stereo plotting system (DOSP) has been developed and put into production. The DOSP-system components are shown in figure 1.

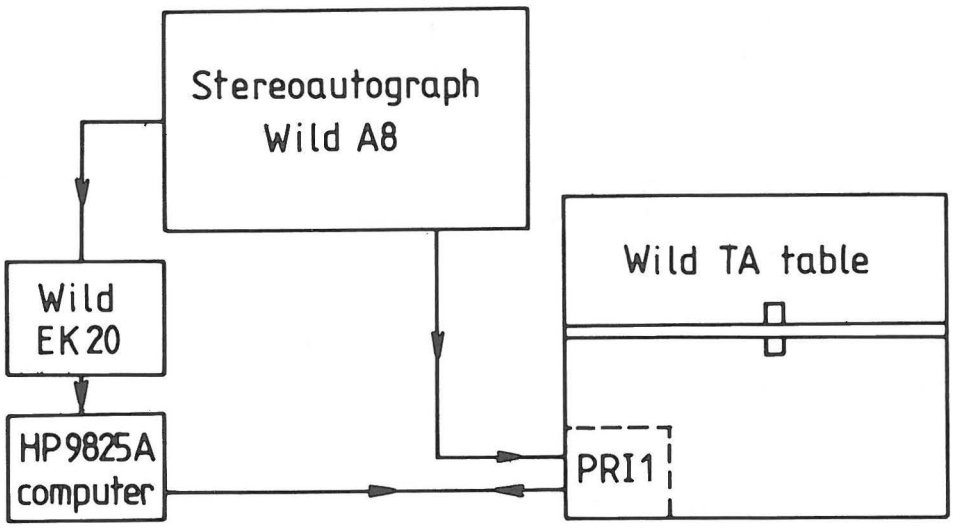


Figure 1. Hardware components of the DOSP-system

The system was developed in close cooperation between an experienced stereo-operator and a computer specialist. Much effort has been made to get the system as user-oriented as possible.

The DOSP-system has two main working modes

A. Digital on-line plotting

In this mode the map features are digitised in the stereo-model and the model coordinates are processed by the HP9825 before being plotted on the Aviotab table by HP9825 commands. The choice of digitising mode is made by the operator by pressing a proper key on the HP9825 according to a symbol overlay on the keyboard.
Single registrations are used to create various symbols (trees, posts, wells, land use, forest etc)
Multi-registrations define polygons made up by straight lines with or without identification tags (e.g. fences) or made up by composed symbols (e.g. hedges). Houses are "squared" when needed. Numbers and text can be generated and positioned.
Automatic registrations are used to create dotted lines. The recordings are buffered and the dots are interpolated with constant interval.

B. Direct mode

In this mode the table is operated in a conventional way. The direct mode is used when drawing continous lines (e.g. contour lines) and dashed lines.

The DOSP-system is production oriented. The map features are digitised to speed up the stereo plotting. A few months of experience has indicated an overall time- saving of 20-40 % in plotting time for a map sheet. It should be pointed out that this is time-saving in comparison with the working procedure with direct inking which again gives a shorter production time than pencil-drawn manuscripts completed by fair-drawing.

Another advantage with the DOSP-system is that the maps contain uniformed symbols and are likely to have a higher planimetric accuracy.

At present the DOSP-system does not create a map data base. The concept of the system however is such that it could easily be expanded whenever needed.

An example af a plot generated by the DOSP system is given in figure 2

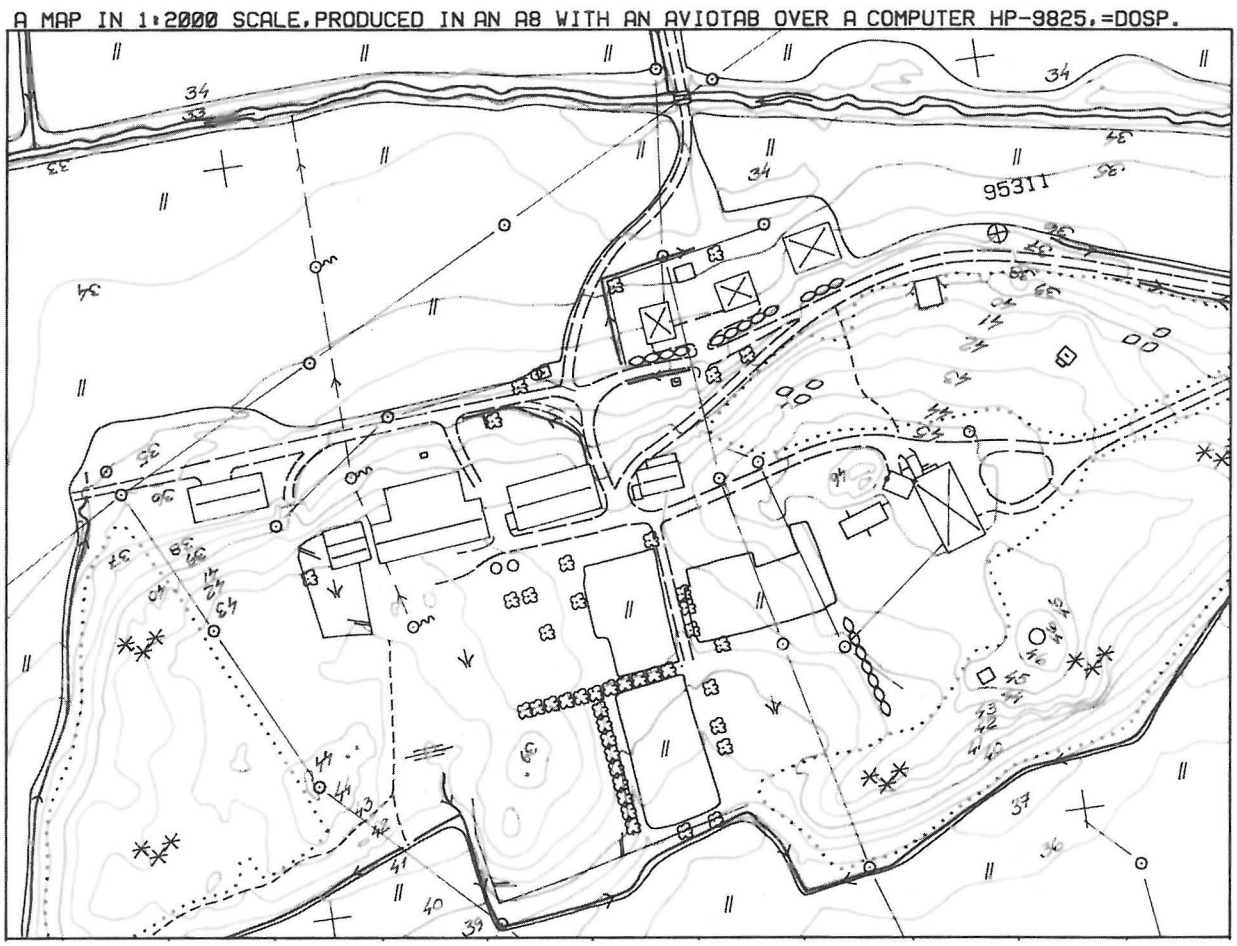


Figure 2. A sample plot from the DOSP-system

2.4 Numerical measurements

Measurements of model coordinates are made for various applications such as the following

- relative model orientation. Y-parallaxes are recorded with ω-or by-digitisers
- absolute model orientation. Linear xy-digitisers are being used
- aerial (model) triangulation
- longitudinal profiles and cross-sections. The measured data are processed in HP9825 and the result is used to compute cut and fill on a large UNIVAC 1100 computer. The measured profiles and cross-sections are also presented graphically on a HP7245 thermal plotter/printer

- reference points for setting out of road centre lines in the field

- reference points for numerical resection of single oblique photographs. Such photographs are increasingly being used in combination with superimposed computer generated perspectives of roads and bridges for presentation of road projects

3. Field surveing

Methods for field surveying and setting out are to a large extent based on EDM-instruments. To-day the following EDM-instruments are owned by NSRA

17	AGA Geodimeter 6	10	Wild Distomat DI10
40	" " 12	14	" " DI3 (S)
2	" " 14	1	" Tachymat TC1
8	" " 120	2	Kern DM 501
2	" " 700		

Some main applications of field surveying technique within design and construction may be mentioned

- photogrammetric ground control
- setting out
- measurement of profiles and cross-section (even polar methods)
- measurement of digital terrain models

At present a great interest is given to the use of solid state memories. Especially during construction stage there are often situations where there is a need for a great number of polar measurements from a few instrument stations (e.g. survey of rock surfaces). There is also a need for interaction between the survey instrument and a computer e.g to calculate a drilling plan for rock excavation and to have the drilling holes set out.

Such total stations can be established in two different ways. In either case a Geodimeter 700 is presently used. In one case the instrument is directly interfased to a desktop computer in the field. The other case is illustrated in figure 3. Data from the instrument are transmitted to a remote desktop computer Hewlett-Packard 9825 by digital radio signals. After processing results are sent back in the same way to the instrument station. A solid state memory is used for storage of data. Necessary polar setting out data are presented on an external display close to the instrument. Various computer programs can be initiated from the field station.

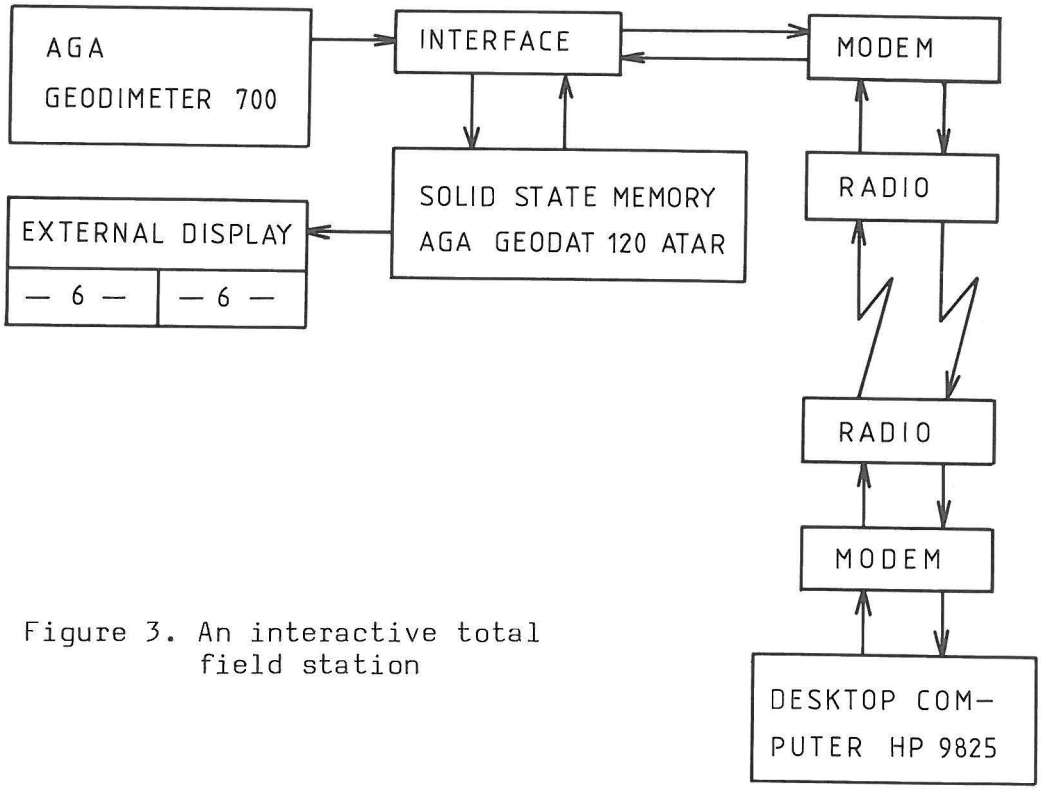
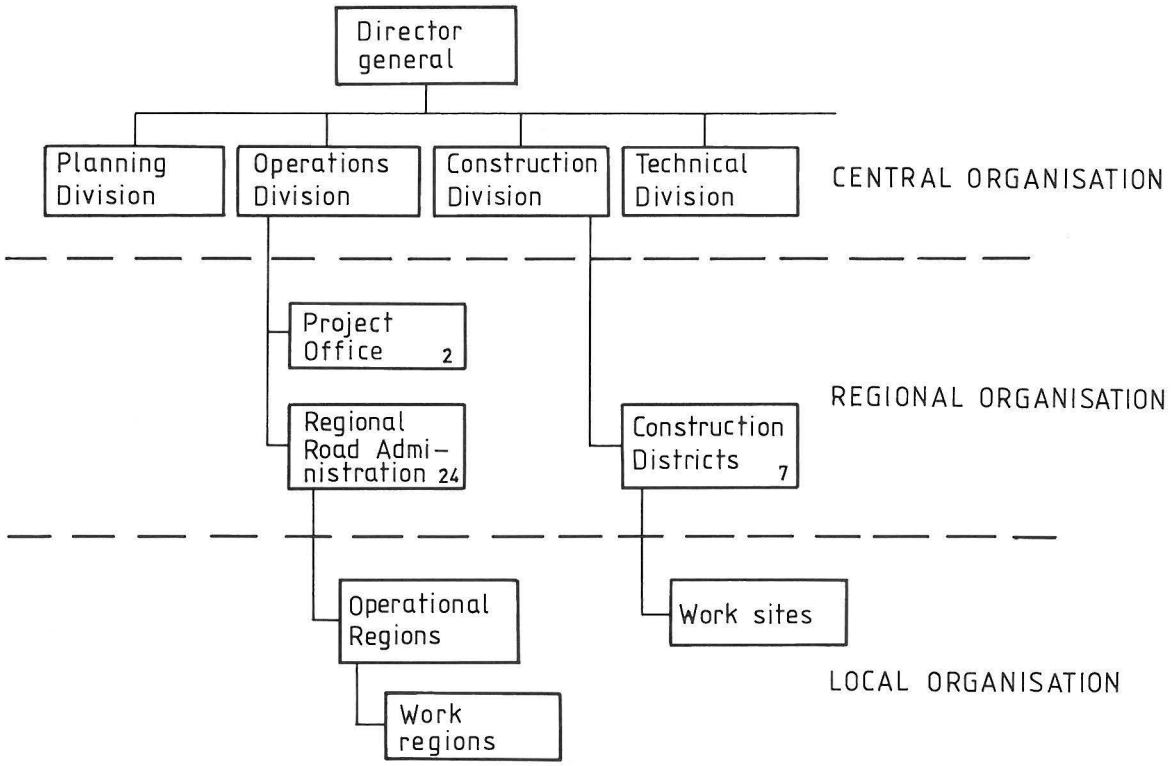


Figure 3. An interactive total field station

4. Organisation

A brief description of the organisation of NSRA is given in figure 4.



NSRA is a decentralized organisation. Design and maintenance are organised in 24 regional offices while construktion is carred out by 7 regional districts.

In each regional unit there is a "surveying engineer" to coordinate the use of field surveying and photogrammetry on the regional level. Corresponding functions are also found in the central organisation.

Development of photogrammetric and geodetic methods applied to road design, construction and maintenance is carried out in cooperation between the operations division, the construction division and the technical division in the central office.

By the end of July 1980 the central office of the National Swedish Road Administration is located in Borlänge, a city appr 200 km north-west of Stockholm.