EXPERIENCES FROM THE TRANSFORMATION, CORRECTION, REVISION AND PRODUCTION OF TOPOGRAPHIC ORTHOPHOTO MAPS OF THE BALTIC STATES USING SPOT DATA - THE POTENTIAL OF SEMI-AUTOMATIC DATA ACQUISITION METHODS

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ABSTRACT

After the liberation of the Baltic states the only existing maps were those produced by the old Soviet mapping authorities, except for the pre-war map series. The maps were erroneous and old, respectively. A topographic map serie is crucial to have for any society. With conventional technology based on aerial photography, the Baltic States would not have been able to obtain this basic information for many years.
During a period of 2-2,5 years a new map serie is produced based on SPOT orthophotos. The maps are produced, specified with a new geodetic datum and a projection specific for all three Baltic states. The production procedures established in the Baltic projects, representing the most up-to-date technology of mapping, include GPS measurements of ground control points, satellite registrations, interpretation, digitizing, data base storage and digital map production. The map and data base project has also been a possibility for the National Surveys to restart their production organizations.
The objective of this paper is to describe production routines and methods using SPOT data combined with other geographical sources to create Topographic Base Maps. The satellite data are even presented as image background in the final map product. Compared to traditional methods, this technique reduces both costs and production schedules without significant reduction in the accuracy of the interpreted features and objects.
Due to the complexity of the projects and the fact that this paper includes production procedures in three countries, the methods describe the proposed solution of the map production. National experiences may result in small modifications of these general methods to optimize the process and the quality of the final data base and map products.

1. INTRODUCTION

During the last decade topographic mapping has experienced extensive changes. Digital processing has become more frequent and efficient, which, of course, is due to the ability to create databases including geographically correct positioned information, increased data storage capacity and reduced cost of equipment. Digitally stored information allows the user to create a flexible and specific map design of the data depending on the features extracted from the data base.

The first contact between the Baltic states and SSC Satellitbild was established in the beginning of the 1990s. Investigations into how to use satellite data for environmental monitoring and natural resource mapping were combined with a search for financing possibilities. The investigations showed that the most urgent need was for digital topographic base maps on a scale of 1:50,000.

The Baltic Base Map project, unique in several ways, relies mostly on the use of the most recent technology in several of the production procedures. The tight time schedule has indirectly determined the layout of the projects. The objective was to create a "complete" data base with appurtenant printed maps, including a smaller number of features and objects compared to traditionally produced topographic maps.

The production routines can be divided into three main parts, briefly described as follows:

- Production of satellite images, which are the main source for the interpretation as well as, naturally, for the geographical position. The objective of this technology is to provide a radiometrical and geometrical quality that makes possible an optimal interpretation result.
- Interpretation and digitalization, including "intelligent" coding to increase the possibility of the utilization of the data base.
- Cartographic map design and printing, using the interpreted and digitized information in combination with a satellite image background.

2. PRODUCTION ROUTINES AND METHODS

2.1 Programming

To optimize the use of the satellite it is possible to select sensor combinations, accepted viewing angles and time periods during the registrations over a certain area.

The final maps include features like forest, agriculture areas, water and urban areas. These and other features are more easily interpreted from satellite data registered during the vegetation period using multispectral sensors than by using panchromatic information. In accordance with this period the multispectral scenes are chosen from the established archive, or programmed. The acquisition period starts at the beginning of May and ends in September-October. The registration schedule for panchromatic information is extended by approximately two months, compared to the multispectral registrations, including the whole snow-free season.
No data included in the project are older than 3 years, an important asset when interpreting the infrastructure and the line information in the panchromatic scenes.

By using registration angles less then ±10° and a generalized DTM it is possible to achieve acceptable accuracy of the geometrical corrections.

2.2 Radiometric correction

The use of different satellites with different instruments makes it necessary to calibrate the information, otherwise problems could occur when comparing data. Calibration within the individual instruments is also necessary, since the sensors are not totally stable in time and some drift could occur in the registered information.

There are small random variations in each detector inside the CCD (charge-coupled device) arrays. Since one detector registers one column in the image, "pushbroom" technique, it is

easy to detect and minimize these differences by a *gain/bias replacement* in raw images.
SPOT imagery, geometrically uncorrected, often displays a regular chess-pattern noise with a period of two pixels. This problem occurred in the early life of each satellite, but has since then been reduced. The reason of the noise is still not fully understood.
A filter is derived, and used by SSC Satellitbild, to remove this *coherent noise* from the un-resampled image before the geometrical correction. (Westin, 1990)
In areas with low reflection i.e. forests and areas with low sun elevation relevant information is registered in only 10-20 quantum levels. The signal to noise ratio is reduced which causes stripings in the images using traditional contrast stretching methods. The problem is solved by multiplying the raw image with a suitable factor before applying the calibration coefficients during the *contrast stretch.*

2.3 Geometric correction

Due to the stable orbit and the fact that satellite motion is subject to the laws of celestial mechanics, it is possible to formulate a mathematical orbital model describing the exterior orientation with a reduced number of parameters. The orientation of one line could then be evaluated based on knowledge of the time for the line registration.

2.3.1 Orbital Model. The satellite image includes a two-dimensional coordinate (line, pixel), which has to be correlated to a three-dimensional geodetic coordinate (latitude, longitude, height). This is done by measuring Ground Control Points (GCPs) i.e. with GPS or by digitizing objects from maps, and locating them in the image. These earth observations are used to update the *a priori* values of the parameters in the orbital model, and this makes it possible to correlate and resample satellite registered information in accordance with the ground truth.
The following list is one way of describing the complexity of the mathematic orbit adjustment model. Transformations between these coordinate systems are calculated, beginning with the information registered by the sensors in the satellite and ending with the ground control points.

- The Sensor Coordinate System describing the detector position errors in the CCD arrays.
- The Attitude Measurement Reference System includes information of the discrepancies in attitude angles according to the zero *a priori* value.
- The Local Orbital Reference System is a moving system describing the position of the satellite mass centre in reference to the earth centre.
- The Earth Centered Inertial Coordinate System (ECI) which has its origin at the mass centre of the earth, and also the orbital parameters referred to it.
- The SPOT Ephemeris Reference System uses the International 1980 ellipsoid for the ephemeris. The information has to be transferred from the SPOT system to the ECI system before it can be used for calculation of orbital *a priori* parameters.
- The Ground Control Point Reference System describes the local geodetic system in which the ground control points are measured.

2.3.2 Sequence of scenes. The continuous registration, "pushbroom scanning", used by the SPOT satellites makes it possible to extend the geometrical correction of one scene to include scenes registered in sequence. The adjustment model will be more complex but it results in a stable adjustment that could include up to five scenes. This method decreases the production time and reduces problems of merging scenes registered in the same strip. (Westin, 1991)

2.3.3 Ground Control Points (GCP). Topographic maps are usually sufficiently accurate for the correction of satellite images on scales around 1:50,000. Investigations show that there is no particular increase of accuracy, with more than seven GCP´s per satellite scene. Experiences from precision correction using maps on a scale of 1:50,000 show RMS errors of approximately 20 metres, caused by digitizing errors, map shrinking and inaccurate geographical position of the objects.

Instead of using maps with low or unknown accuracy, it is possible to produce satellite images as a concept for the control point measurement. By using three to four points within each raw scene it is possible to optimize the GPS measurement according to the orbital model and geometrical correction of a sequence of scenes, still achieving RMS errors during the adjustment of around five metres.

The optimal method of measuring GCP´s with Global Positioning System (GPS) was investigated and evaluated by students from the Royal Institute of Technology in Stockholm, (Dahlgren, Svedjesten, 1993). Two methods briefly described as follows was evaluated according to the criterion to find out methods resulting in RMS errors not exceeding five metres.
Static observation, occupies the control point until enough data has been registered from the satellites. This is the most accurate method and the one traditionally used, resulted in a RMS of 3.4 m during the geometric correction in 2-dimension.
The results of the investigation show that an increase of the two parameters of major interest for the evaluation, observation time 15 min and baseline distance 50 km, did not significantly improve the insufficient RMS error.
Kinematic observations, allow placement of the receiver on the roof of a car. Measurements can then be performed during the movement through the road intersection. This measurement was done from both the crossing roads and results in two crossing vectors, which allows calculation of the centre of the intersection. The result of the observations, RMS 4 m, shows that this technique has a very high potential for automatic processing in the nearby future.

2.3.4 Digital Terrain Model (DTM). It is necessary to use a Digital Terrain Model, DTM, to reduce the influence of the oblique viewing angle and the terrain altitude. The DTM could be processed from a SPOT stereo pair by automatic matching, using methods as Multi-Point-Matching (Rosenholm D., 1987) or Match-T. For reasons of cost and time it would not be rational in these projects since contour lines already exist in the old maps.
Digitized contour lines from different map sheets was edge connected to each other before any further processes could take place. The digitized and coded contours was then transformed to the Baltic system, using transformation parameters, described in paragraph 2.3.7.
The digital contour lines was used as input to a Digital Terrain Model interpolation program TIN which creates triangles according to the digitized breakpoints in the vectors. The regular DTM grid was then interpolated from the three height values of the triangles. It is important to use approximately the same distance between the breakpoints in one contour line as to the nearest digitized line with different elevation.

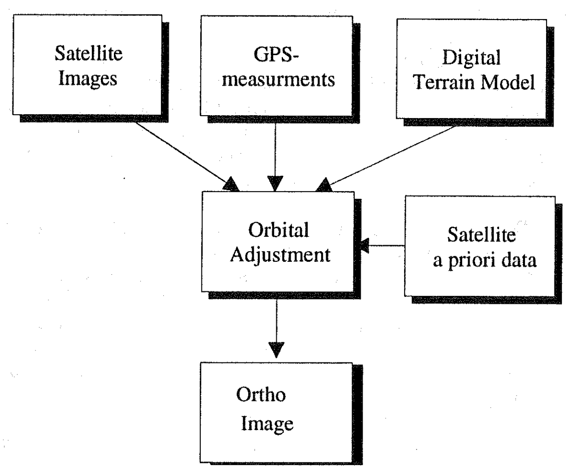

Fig. 1. Geometric correction

2.3.5 Geodetic systems. The system is based on the GRS 1980 ellipsoid with parameter values almost similar to WGS 84, the ellipsoid used for GPS positioning. The Soviet Union system uses the Krassovsky ellipsoid. First order points in the net are connected and adjusted together with points from Finland, Poland and Germany.

2.3.6 Map projections. The Baltic projection parameters are rather similar to the parameters used in the standardized Transverse Mercator Projection, Universal Transverse Projection, UTM. Because of the longitude location of the countries it was not convenient to use the standard meridian suggested in UTM. In order to minimize distortions in the central parts it was decided that the central meridian should be centered in the Baltic states. All other parameters are similar to UTM parameters.

2.3.7 Transformation. Since the old Soviet Union geodetic datum is unknown, some of the points in the old geodetical net have been measured by GPS. Transformation parameters are then calculated between the two systems using well defined positions in the Soviet system and the same points measured and transformed to the Baltic system using a 7-parameter transform, including 3-dimensional translation, 3-dimensional rotations and a scale factor.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{Baltic} = \begin{bmatrix} \Delta X_0 \\ \Delta Y_0 \\ \Delta Z_0 \end{bmatrix} + m * \begin{bmatrix} 1 & rz & -ry \\ -rz & 1 & rx \\ ry & -rx & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SovietUnion} \qquad (1)$$

Calculation of these transformation parameters has made it possible to use information from the old Soviet Union topographic maps as reference material in the projects. Hydrographic information is an example of a feature that has been selected and digitized from the old maps.

2.3.8 Image Processing. By using image enhancement filtering the interpretation results can be optimized. In this case two different methods are combined and included in the production process. The standard corrected images are DEHAZE filtered which strengthens the edges between light and dark features in the images. DODGING adjusts global contrast differences. In practice this means that dark areas, like forests, will become somewhat lighter, and light areas will appear somewhat darker. Finally, when combining two or more scenes in a mosaic, it is important to correlate them spectrally, to increase the interpretability and to present a more homogenous product for the image background without seam strips between images.

2.4 Products delivered by SSC

For a combination of technical and cost reasons it was decided to produce the panchromatic information on a scale 1:50,000 and the multispectral on 1:100,000. According to SSC Satellitbild´s production routines the corresponding spatial resolution of the digital data is 10 and 20 metres respectively. The panchromatic information was delivered as map sheets related to the new Baltic map sheet index system and the multispectral images as precision corrected scenes.

2.4.1 Digital Products. The digital data was delivered on CD-ROM with a storage capacity of 600 Mbytes. As the image data includes merely image information, the data describing map projection, ellipsoid, resolution, etc. has to be specified. SSC Satellitbild has developed a GIS format including description files on the size and layout of the image raster file, on the map projection, map sheet and on the different sources used for producing the image. They are presented separately from the image data, in an ASCII file, because different image processing software use these descriptive data in different ways, making it possible to use the information independent of software.

2.4.2 Photographic products. Satellite data was presented in two types of photographic products, paper prints and transparent films. Film is a more stable material than photographic paper with regard to shrinkage and expansion from variations in humidity and temperature. On the other hand, unlike photo-paper transparent films require light-tables for their interpretation and cannot, therefore, be used in the field.
Panchromatic (Black and White data) on a scale of 1:50,000 was delivered as both paper prints and transparent films and multispectral data on a scale of 1:100,000 as paper prints, with a plastic base giving a stability similar to that of transparent films.
Furthermore the shrinkage and expansion errors, of about 2-3 mm on a print of 50 cm, could easily be minimized with a affin transformation in 2 dimensions.

2.5 Interpretation

Information possible to interpretate from remotely sensed registrations is in general of the "land cover" category, which is an interpretation of vegetation, water, open areas etc. Traditional maps usually present "land use" features implying that some evaluation has been added during the interpretation of the images to convert from land cover to land use information.

2.5.1 Information sources. *Existing digital data bases,* digitized from topographic maps on a scale of 1:50,000 contain

- coastlines
- lakes
- watercourses
- wetlands
- build-up areas
- road network (three classes)
- railways
- administrative boundaries
- peat extraction fields
- contour lines with 20 m equidistance
- name data base (being developed)

All these elements have to be transformed from the old datum to the new Baltic geodetic datum. The data from the old maps serves mainly as a complement to the satellite image data during the interpretation.

Satellite images. The area covered by each panchromatic Satellite Ortho Photo Map is 25*25 km. Most of the SOMs contain information from two or more satellite scenes, optimally mosaicked for the base mapping purpose. Due to the oblique registrations of the satellite data it has been necessary to use a Digital Terrain Model to eliminate displacement errors caused by terrain variations. The multispectral data geometrically processed in the same way is particularly suitable for area interpretations, such as land cover information.

Other sources. Available existing Maps on a scale of 1:10,000 - 1:100,000, aerial photographs and field studies in combination with local knowledge and competence concerning the land and its resources is in general the best ground truth data.
Investigations of name data was a highly time consuming part of the mapping, due to the 50 year mapping period with Russian names spelled with Cyrillic letters.

2.5.2 Legend. Before starting the actual interpretation work, a legend has to be established containing all types of objects to be interpreted. Forest for example have to be precisely defined by crown cover density before the representation in the satellite imagery was investigated.
Since areas, that are not always homogeneous it is important to clearly define the boundaries and priorities between different classes to minimize possible ambiguity during the interpretation. This was done between all pairs of classes.

2.5.3 Methods. Three alternative production methods have to be considered depending on the quality of the sources.

- Updating of existing digitized data. This method is efficient when the revisions are limited. It should be noted that the editing of data bases is highly time consuming.
- Interpretation of recent satellite images as the main source of information. In some cases it could be necessary to use existing maps as support for the interpretation.
- The use of already digitized data in cases when interpretation of the object from the images is not possible, such as contour lines and administrative boundaries.

Areas. A preferable way to start a project of the current dimension is to separate the simplest area features from each other, land vs. water. The following order of priority is adopted for the features included in the projects.

1. Water, interpreted mainly from satellite images.
2. Agricultural areas, from satellite images with some help from maps.
3. Urban areas and settlements, from a combination of satellite images and maps.
4. Exploited areas, from satellite images and maps in combination.
5. Mires and wetlands, from satellite images and maps in combination.

All remaining information are classified as forest.

Lines are more time consuming to interpret than area information owing to the need for external information to achieve a satisfactory result. Road information, for example, could be extracted from road maps, including different classes of the object. Finally, field studies could be necessary to investigate missing information.

Symbols. Most of the symbols are extracted from external sources and then correlated to areas and lines interpreted from the satellite images in combination with existing maps.

2.5.4 Materials and technique. Lines and areas are handled on separate originals. This could create problems when a line, like a road, coincides with a field boundary. In the data base these two lines have to be identical, otherwise problems will occur when finally creating a printed product from the data base.
Two main methods could be used during the collection and conversion of analogue information to digital data.

- Digitizing and coding of the features from the original manuscripts.
- Scanning the original, vectorizing and coding of the features.

These methods are suggested to reduce the need for computer power. A third method, including screen editing and digitalization of objects, using a geometrically corrected satellite image as background, requires powerful computers to visualize the images.

2.6 Data Base and Map Design

One of the main advantages of storing map information in digital data bases is the flexible post-processing of the data. It is not possible to make any major changes easily in the layout of traditionally created maps. Objects from digital bases could be created in an endless number of designs, all due to the customers' requirements. It is also possible to select elements of interest for the specific map product.
The development of printing equipment and the reduced "fitting" problems between different printing originals has made it possible to use the 4-colour printing technique. These originals are usually combined with a separate original for the black text to be included in the map.

2.6.1 Data base. A geographic data base traditionally includes information digitized from maps. Due to this fact, it is important that the data base handler includes satisfactory solutions on the following criteria.

- Flexible area selection from the base, map sheet independent. Area boundaries selected by polygons or edge coordinates.
- Extraction of features of editing or mapping interest.
- Lock information for other users during the editing.
- Log files, describing feature events during the data base history.

Elements included in the data bases produced by the Baltic states are coded in accordance with the Swedish standard, KF-85, where all codes contain seven digits divided into three levels

xx	xx	xxx
Title	*Object group*	*Object*

Example

Highway	30 11 000
Main road	30 13 000
Local road	30 24 000
Field/Forest road	30 27 000
Bridge	30 xx 230

All interpreted digital data are checked before being stored in the Data Base.

2.6.2 Map Design. The final map design is a result of a iterative work with employees from SSC Satellitbild, LM-Kartor and most of all with representatives from the respective Clients in the Baltic countries. A number of prototype maps was produced, not only to evaluate single elements but also to find a cartographic balance in the final map product. This balance is of special interest in this case because the resulting map includes an image background produced as a mosaic from satellite images. The satellite background mosaic leaves the interpretation to the end user, thereby compensating the reduced number of features superimposed on the map.
Owing to the printing technique it was decided to present contour lines in gray. The traditional colour of contour lines is brown, but the 4-colour printing method would possibly have caused matching problems between the printing originals yellow, magenta and cyan.
All text has been printed in black, except names of water which are presented in blue. Some names are rastered in the same value as the boundary they correspond to, for example parish names.
Due to the need for some special characters it was decided to use PostScript format, which allows the user to create personal letters, not included in US standard.

2.6.3 Image Background. Three versions of the black and white satellite image are produced to optimize the visualization of forests, agricultural areas and build-up areas. These features are presented in different colours in the final product.
The 4-colour printing technology is based on the use of RGB-complement colours in the subtractive process. This fact explains the need for a program converting RGB colours to the CMY(K) system allowing printing on paper. The software market offers such facilities, but the current extreme case with just green colour, in different brightness, presenting forest areas must be handled as a special case of transformation between these two colour systems. A simple but efficient method was investigated and established to allow optimal vizualisation in forest and agricultural areas.
Instead of transforming the whole "colour body", each channel is converted from RGB, or more correctly the channels included in the black and white RGB image, to either Cyan Magenta or Yellow. This conversion is done by using a Look Up Table (LUT) which describes the relationship between input and output values of the gray levels in the image to be processed. The information from 3*256 gray-levels in the RGB system has to be inverted to the CMY system according to the different ways to create colours. For example, 0 intensity is represented as black in RGB and as 100 percent in the inverted CMY. This step is included in the LUT used for the transformation from RGB to CMY.

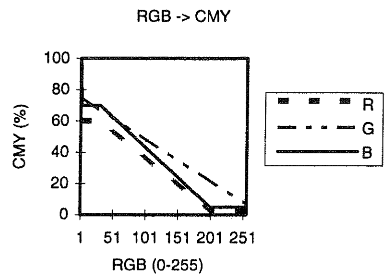

Fig 2. Look Up Table, RGB -> CMY

The green forest colours have been created as composites of Yellow and Cyan, using percentages described in the LUT. The agricultural areas have been more complicated, due to the perception of the eye in yellow colours, reducing the amount of information in those areas. This problem is solved by calculating a black contrast image and recalculating the values of the three other colours. Each image pixel is calculated as follows.

K = min (C,M,Y) "contrast image"
C = C - K
M = M - K
Y = Y - K

Recalculation of the colours (CMY) reduces the darkening influence of the black colour, which is favorable since it gives an image with higher contrast, without any darker prints. In the agricultural areas the yellow colour in combination with the black contrast image is used.
By a "powerful" contrast stretching, it is possible to use the B/W-image in urban areas, especially to show the road network.

2.6.4 Printing Originals and Printing. Five printing originals are produced, CMYK plus, in conformity with traditional methods, one extra black for text information. In the current projects, the black original also includes contour lines and symbols, which allows a simpler production process.
Different raster angles are used on the originals to avoid moiré effects, causing undesirable, patterns in the printed map. During this production the angles of each colour is calibrated to minimize this problem.
The exact fitting between the originals during the printing process is especially important in the 4-colour technique used in the current projects. Inexact fitting results in shadow effects and unhomogeneous colours. Tiny lines, including two or more colours are particularly sensitive to such negative effects.

2.7 Quality Control

In projects of a magnitude comparable to the Baltic Base Map projects it is necessary to include quality check points in the production process. This is done in three steps, described briefly as follows.

2.7.1 Image Control. This quality check has been performed by SSC before the images and digital data was sent to the Baltic states. During the precision correction of the satellite information, the accuracy of the adjustment is described as an RMS error and its residuals. The values and directions of the residuals are checked by the operator before the image resampling is performed. The satellite information was checked before deliverance in accordance to expansion and shrinkage errors, image radiometry and annotation information.

2.7.2 Data Base Control. For each map sheet delivered from the customers in the Baltic States to the final production of printing originals in Kiruna, the elements included in the digital information are checked in accordance with a verification plot. The check has been done in an iterative way, including still another control of the revised data before delivery. For obvious reasons this part of the production check has to be performed by the interpretators in the Baltic States having local knowledge of the areas in question.

2.7.3 Printing Control. A verification plot was produced using the printing originals as input. A check and acceptance of this proof print by the responsible personnel completes the quality control of the Base Map printing originals.

2.8 System Design

The configuration of hardware and software packages was discussed in the initial part of the projects with responsible personnel from all three countries. The final solutions include already existing equipment combined with new installations, configured to optimize the production facilities within the Base Map Projects.
Workstations and Personal Computers are connected to a local data net, which allows efficient data transfer. A plotter for verifications and a tape recorder as backup facility are also connected to the net. The tape recorder back up was also used as delivery media in the initial part of the projects, but the fast development and installation of the Internet allowed more efficient ways of distributing data between the countries. Vector data has later been transferred by net to Sweden.
As the data delivery from SSC is made on CD-ROM´s, a CD-reader is included in the local net. An advantage of using CD´s for storage of image data is the possibility of using the CD-reader as an external disc, which minimizes data storage problems on the internal WS-disc.

3. RESULTS and DISCUSSION

The production procedures established in the three projects include GPS measurements as ground truth data, satellite image registrations, interpretation, digitizing, data base storage and digital map production, representing the most up-to-date technology of mapping.

Orthophoto accuracy. The accuracy of the GPS measurements in the projects was an RMS of less than 5 metres, which is sufficient using the satellite orbit adjustment model developed at SSC Satellitbild. It is concluded that, in comparison with traditional methods using control points digitized from topographic maps, including RMS errors of approximately 20 metres, GPS measurements greatly increase the accuracy of the satellite images positions.
Digital Terrain Models are used to reduce the influence of terrain variations and non-vertical viewing from the satellite registration. The maximum magnitude of this influence was calculated to 53 metres. By using a simple DTM, with a height accuracy of 25 metres, this error was reduced to a level of 5 metres.
A total RMS of less then 10 metres, GPS + DTM, corresponding to 0.2 mm on a scale of 1:50,000, satisfies the required delivery quality of satellite products used for the production of data bases and maps in similar scales.

Methodology. As the geometry of the satellite information is more accurate than a cartographic map product, the location of the elements in these projects are related to the satellite imagery position. An investigation, performed in cooperation by Swedish Space Corporation and the National Land Board of Sweden, has verified that images registered by the SPOT satellites are accurate enough for interpretation and updating of topographic maps on a scale of 1:50,000 (Engberg A, Malmström B, 1991).
Satellite images covering 60 * 60 km^2 imply advantages compared to traditional remote sensing using aerial photos due to the size of the homogeneous area registered, which in combination with information from different sources during the production, optimizes the interpretation capability.
A flexible defined methodology allows the most efficient usage of external sources during the production. Due to the quality of the non-satellite data it was early decided to use mostly national information as a complement to remote sensing data registered by the SPOT satellites. Editing experiences show, in general,

that updating of existing cartographic data bases is much more time consuming than an initial production of a GIS base related to geometrically correct sources. By the use of satellite images as background information it is possible to reduce the number of interpreted features, which allows a reduced time schedule compared to traditional mapping while maintaining quality, without any significant reduction of the interpretability of the final map product.

Database. Experiences from these three Baltic data base and mapping projects amplify the impressions from earlier data base establishment projects. Data bases generally include information stored from digitized maps, based on cartographically handled information. Today this information is not accurate enough when combining the cartographic data with geographically correctly positioned information in a GIS environment.
Homogeneous data base quality is of greatest importance for future data usage in combination with external sources. The quality of the data from the Base Map projects allows a combined use with external data sets for production of among other things thematic maps. In other words, the information stored in the data base, with its well-defined geometry and coding, constitutes a platform for further data and map projects.

Map design. When evaluating the map design of the three Baltic projects, the main technical purpose which is the establishment of a flexible data base, has to be taken into account. The reduced time schedule, which results in a map product containing an image background as complementary information to interpreted and coded features, has an effect on the cartographic balance and layout. Topographic maps in general do not include image backgrounds, which resulted in the need for investigation and development of production procedures optimizing the use of satellite data in combination with traditional feature information.

Education. The development of personal skills using remote sensing products in a digital environment, is an aspect that should not be overlooked, during such big projects. In combination with the development of interpretation and GIS procedures such projects include the whole spectrum of the latest techniques in map production.

Time schedule. Due to the minimized production time of these projects it was necessary to optimize the production procedures with remained expenses. This resulted in the following possibilities and decisions:

- Initial training including remote sensing, interpretation technique and GIS.
- Satellite Ortho Photo Maps as main sources during the interpretation.
- The number of GPS measurements as ground truths was minimized by the usage of SSC Satellitbild's orbital adjustment model.
- Efficient usage of existing information, i.e. contour lines.
- Data Base structure in accordance with the Swedish KF85 nomenclature.
- Lowered ambition of interpreted features, compensated by an image background.
- Analog interpretation, instead of time consuming screen interpretation and digitalization.
- Digital cartography, using coded vector data as input to the map design environment.
- Digital data delivery via the Internet.

4. CONCLUSIONS

Position accuracy in orthophotos, geometrically corrected by GPS measured GCP:s and a generalized DTM, based on panchromatic SPOT data on a scale of 1:50,000 in combination with multispectral data on a scale of 1:100,000 are feasible information for revision of topographic maps on a scale of 1:50,000.

The homogeneous data base quality, high geometrical accuracy and "intelligent" coding, allows effective data extraction and further combination with external data sources.

A balanced cartographic product, combining satellite images and interpreted features from different sources, without any decreased quality, verifies the value of topographic base mapping projects.

A combination of initial education (remote sensing, interpretation and GIS) followed by production is an efficient method for technical transfer during mapping projects similar to the Base Mapping Projects in the Baltic States.

By using a digital technique, methods performing semi-automatic revision of existing data bases, it will be possible to increase the position accuracy and also reduce the time consuming part, manual interpretation, of data base revision projects in the future.

5. REFERENCES

CNES and SPOT Image, 1988. SPOT user´s handbook.

Dahlgren A., Svedjesten L., 1993. Control Point Determination with GPS for Precision Correction of SPOT Satellite Images. Master of Science Thesis. The Royal Institute of Technology, Department of Photogrammetry, Stockholm, Sweden.

Harris R., 1987. Satellite Remote Sensing - An Introduction, Routledge & Kegan Paul.

Krusberg P., 1994, Estonian Base Map Project, Estonian Map Center.

Malmström B., Engberg A., 1991. Satellitedata for Topographic Mapping, Swedish National Land Board, Swedish Space Corporation. (Swedish)

Rosenholm D., 1987. Some Aspects of Least Squares Matching for Automatic Parallax Measurements. The Royal Institute of Technology, Department of Photogrammetry, Stockholm, Sweden.

Westin T., 1991. On the Estimation of Interior and Exterior of SPOT Imagery. The Royal Institute of Technology, Department of Photogrammetry, Stockholm, Sweden.