**Nationaal Lucht- en Ruimtevaartlaboratorium**
National Aerospace Laboratory NLR

NLR-TP-2000-397

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# USE OF REMOTE SENSING IMAGERY FOR FAST GENERATION OF MILITARY MAPS AND SIMULATOR DATABASES

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Working Group IV/3

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## ABSTRACT

For military purposes it is of importance to have at one’s disposal actual and accurate terrain information for specific areas of interest anywhere in the world. Geographic information forms only one, but quite essential, aspect in this context. On the one hand the information is of importance as a basis for command and control. On the other hand it is of importance for the operation of individual weapon systems, which all use their own information database. In this framework the Netherlands Ministry of Defence initiated a project called Remote Sensing for Royal Netherlands AirForce Applications (RS-KLuA). This project focuses on the demonstration and evaluation of the capabilities of Remote Sensing data for the generation of geographic information products for three selected Royal Netherlands AirForce (RNLAF) applications: flight simulation, mission planning and air-defence planning. For a test area around Freiburg (GE) four different products were generated and evaluated for the applications. The project is not finished yet, but it already can be concluded that for all three applications remote sensing data can provide relevant geographical information products, ranging from DTED and DFAD files to natural color imagery data and raster map products. Most products can be generated or updated relatively fast, and the required remote sensing source data can be available within a short time and in an independent way. The products can be of value for situations were no alternative products are available at all, even if the quality would be worse than the normally used information. Further the products can be of value for the updating of available geographic information. And finally the information can be of value, because it provides an additional new type of information with which the functionality of the application can be extended.

## 1 INTRODUCTION

For military purposes it is of importance to have available actual and accurate terrain information for a specific area of interest anywhere on the world. The latest crises in Iraque, Bosnia and Kosovo all illustrated that the success of military operations is increasingly depending on the availability of good information and a good information infrastructure. Geographic information only forms one segment of this story, but well an essential one. Geographic information on the one side is of importance as a bases for the command and control. At the other side it is of importance for the operation of individual weapon systems, which all use their own information database. In The Netherlands the Ministry of Defence initiated a project focussing on the demonstration and evaluation of the capabilities of Remote Sensing data for the generation of geographic information products for a number of selected Royal Netherlands Airforce (RNLAF) applications. The project was called Remote Sensing for Royal Netherlands Airforce Applications (RS-KLuA). It started at the end of 1998 is planned to be finished in June 2000.

## 2 MILITARY APPLICATIONS AND THEIR INFORMATION REQUIREMENTS

### 2.1 Applications

The RNLAF selected three applications, for which the use of actual and accurate geographic information is of importance: Mission Simulation, Air-defence Planning and Mission Planning.

### 2.1.1 Mission Simulation

*System Description:*
For Mission Simulation the NSF (National Simulation Facility) flight simulator was selected. NSF is a modular research flight simulator. For the project the simulator is configured for the F16-MLU cockpit. Both motion, sound, and vision

are simulated, including the environment (targets and threads). For this project the visual system of the simulator is of importance. This system uses an Evans & Sutherland ESIG-3000 computer image generation system which generates three image streams. Two of them are used for the Out-of-the-Window scene. A head-tracked projection system is mounted inside a 17-ft dome, which is mounted on a 6-DoF (Degrees of Freedom) motion platform. It gives a total possible Field of Regard (FoR) of nearly 360°. The head-slaved image consists of an oval background Field of View of 140° horizontal by 110° vertical, in the center of which is a high-resolution inset with a Field of View of 50° horizontal by 35° vertical. A database modeling system is available.

*Data Requirements:*
The geographical data requirements for the outside visual of NSF are as follows:

- Terrain elevation information: for this DTED level-1 information is used
- Terrain coverage information: this information is visualized on top of the relief. It can be built up in several ways:
  - As global texture: a photo (bitmap) with geospecific texture is draped over the DEM
  - As a vector database in combination with a library of geotypical textures and a library of 3D polygon models: For this DFAD information can be used. Based on the DEM and the DFAD information the terrain is split up in triangles, which are filled with textures out of the texture library. For a selected number of features 3D polygon models out of the model library are used and placed on top of the terrain.
  - A combination of the two mentioned ways: global texture from a geospecific image, with a selected number of specific features taken out of the DFAD database and presented in geotypical texture on top of it, and added to that 3D polygon models for some special DFAD features.

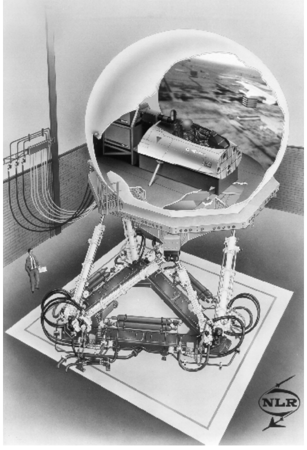

Figure-1: NSF system set-up

For mission rehearsel it is of importance to have the ability to feed the simulator with actual, accurate and realistic information of a certain area of operation within a short time. Actuality at the moment is a large problem, because the DFAD data often is more than 20 years old. Accuracy of the DFAD data is also often very limited, for many areas e.g. roads and other transport lines are missing. DTED level-1 data is not available for many areas in the world. Realistic display of the environment can be increased by using natural-color photo data. Remote sensing data can be used

### 2.1.2 Air-defence Planning

*System Description:*
For air-defence planning the FELCOP/INDIA application was choosen. FELCOP is a PC-based application that helps deployment planners to find favorable sensor positions for air defence systems (Patriot and Hawk). The program enables the user to analyse an area of operation by means of digital terrain maps and terrain cross sections. When a promising position has been found, FELCOP can quickly generate a line-of-sight coverage diagram, which gives the user insight in the suitability of the location. A digitized terrain database is used to calculate the coverage diagrams. Terrain data are derived from the Digital Land Mass System (DLMS), a standard available to all NATO members. Terrain is modeled in a 100 meter resolution grid, where each grid cell contains information about the soil height, culture type (water, industry, wood etc.) and culture height. INDIA (the INtercept DIAgrams model) is a more extended program, also providing quantitative measurements of the defensive quality against air defence guidelines. Together with the intercept diagrams this should give the air defence planner enough information to make an objective deployment choice, depending on his air defence mission, which determines the relative importance of his six guidelines.

*Data Requirements:*
The geographical data requirements for FELCOP are as follows:

- Terrain elevation information: DTED level 1 data is generally used; (horizontal resolution 100 m, vertical resolution 30 m). Near the planned sites to deploy the sensor systems more accurate elevation data (DTED level II, horizontal resolution 30 meter, vertical resolution 15 meter) may be advantageous.
- Terrain coverage information: DFAD data. Terrain data with different culture types is used. For culture types, like forest, industry and urban, available height information is relevant. Striking points, waterways and roads are used for orientation in the scene, while roads are also important to estimate the ability for accessing the planned sites.
- Terrain coverage information: Photo raster data

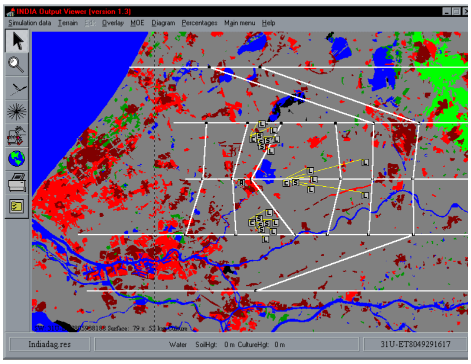

Figure-2: FELCOP/INDIA intercepts

In general for FELCOP it is of importance to work with actual terrain information, for which remote sensing information can be used. Besides remote sensing data can be used to improve the accuracy of the model calculations, as a consequence of more actual and complete DTED and DFAD information. Also remote sensing data can be used to improve the recognition of the terrain. On the one hand this can be improved by also displaying line and point elements in FELCOP, in case these information is available in the DFAD data. On the other hand photo raster data can be used as an additional background.

### 2.1.3 Mission Planning

*System Description:*

For mission-planning MSS/C was chosen. The mission support system MSS/C is a powerful tool for military mission planning. It enables aircraft pilots to familiarize with the battle theatre and to compose flight routes. MSS/C deals with current flying restrictions, weather conditions and threats in both the friendly and enemy areas. The present MSS/C consists of three main components: scenario, planning and output. Scenario presents all data related to geographical co-ordinates, formatted in overlays, on a continuous map on a scale selected by the user. Planning sessions start with an overall assessment of the feasibility of the mission to be executed and with the weapon loading related to the mission objectives. The trajectory planning of the mission consists of three parts: the route to the destination area, the manoeuvring (e.g. attack, combat air patrol) in the destination area and the route from the destination area to the home base. MSS/C uses a database with data about geographical features, besides data about friendly and enemy assets. Two types of electronic maps are used: maps generated by DMA, in the Arc Digital Raster Graphics standard (ADRG) and maps generated by NLR by scanning paper maps, using the Map Sheet Conformal Projection System (MSCPS).

*Data Requirements*

The geographical data requirements for MSS/C are as follows:

- Terrain elevation information: DTED level-1 information
- Terrain coverage information: For this scanned paper maps at scales of 1:500k to 1:50k are used

For areas where no accurate DTED information is available, these can be generated out of remote sensing data. For the availability of actual and accurate terrain coverage information remote sensing can be used to update map-products or to provide different sorts of image-map products.

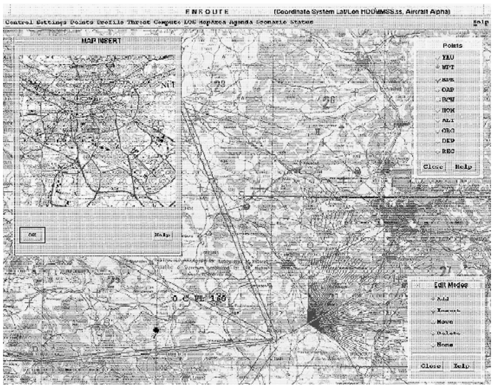

Figure-3: MSS/C route planning

### 2.1.4 General Data Requirements

Reviewing the information requirements for the three applications, some conclusions can be drawn.

- For all applications a sub-division can be made between terrain elevation and terrain coverage information.
- Most applications are using DTED level-1 and DFAD level-1 data
- Remote sensing data can be used to:
  - Provide a means for updating the actuality and quality of existing DTED and DFAD information.
  - Provide an alternative for the (fast) generation of actual and accurate DTED and DFAD information in case this is not available.
  - Provide additional information with which the functionality of the applications can be extended.

In table-1an overview is given of the possible information sources for the different applications.

| | DTED | DFAD | Raster-photo | Raster-map |
|---|---|---|---|---|
| NSF | ● | ● | ● | |
| FELCOP/INDIA | ● | ● | ● | ● |
| MSS/C | ● | | ● | ● |

Table-1: Possible information sources for the three applications

## 3 TEST AREA AND DATASET

### 3.1 Test Area

A number of criteria for the test area were of importance. It should have both flat parts and parts with relief. Further different types of terrain coverage should be present, like agricultural, built-up and forestry areas. Also variation in features like roads and water ways should be present. Based on these criteria and the data already available the area of Freiburg was chosen. In figure-4 an overview is shown. To the west of the city Freiburg, the Rhine and the Rhine

Valley are included. To the east of Freiburg the Black Forest is present including the highest peak (1493m), see also the DEM in figure-5. The Rhine Valley is an agricultural area including many lines of transportation, like (rail-) roads and waterways. The Black Forest is covered with forest with in the valley agricultural fields and villages. For the NSF flight simulator a larger area was required in order to fly a full mission, shown in figure-6. For this application a mission was planned from the Dutch airbase Volkel to Freiburg and for the whole route data was acquired for a strip of about 50km.

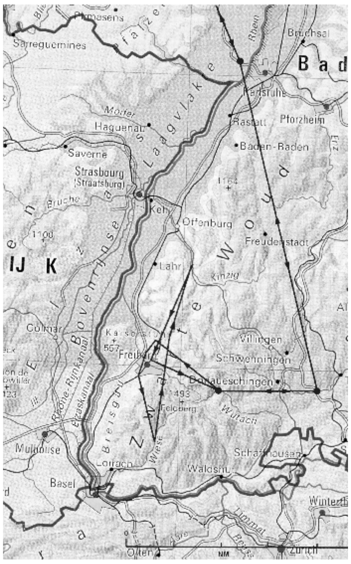

Figure-4: Freiburg area

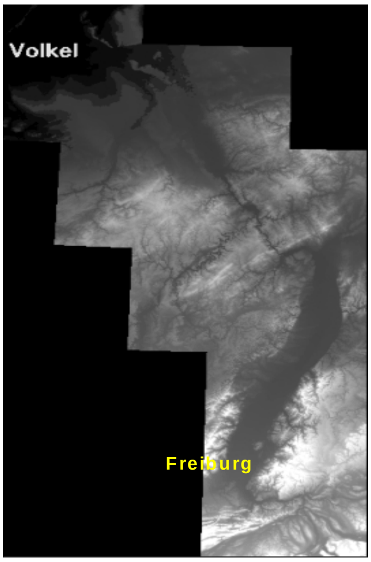

Figure-5: DEM Volkel-Freibrurg

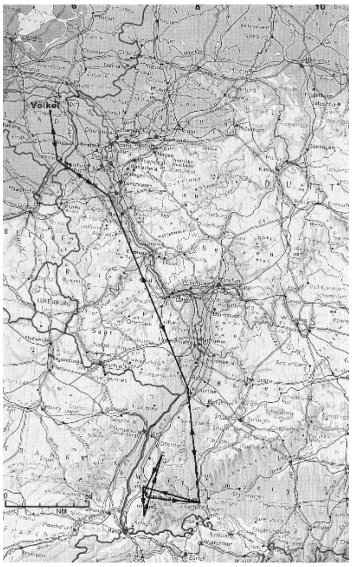

Figure-6: Route Volkel-Freiburg

## 3.2 Test Data

All kind of different space-borne and airborne remote sensing data were acquired. Also paper maps and DTED and DFAD files were available. An overview of all available data is shown in table-2.

| **Sensor** | **Platform** | **Type** | **Resolution (m)** | **Area (km)** | **Date** |
|---|---|---|---|---|---|
| Landsat TM | Space borne | Optical-MS7 | 30 | 90*90 | 94-06-24 |
| | ’’ | ’’ | ’’ | Route | 1991/95 |
| SPOT-XS | Space borne | Optical-MS3 | 20 | 60*60 | 89-05-09 |
| SPOT-Pan | Space borne | Optical-pan –29.6deg | 10 | 60*60 | 94-07-02 |
| | ’’ | Optical-pan +0.00deg | ’’ | ’’ | 94-08-04 |
| | ’’ | Optical-pan +25.5deg | ’’ | ’’ | 91-08-06 |
| Aerial B/W Phot. 1:70k | Air borne | Optical-pan | 2 | 30*30 | 92-09-17 |
| Aerial B/W Phot. 1:32 | Air borne | Optical-pan | 1 | 10*10 | 90-08-24 |
| DPA MS-scanner data | Air borne | Optical-MS3 | 1 | 6*6 | 95-07-01 |
| ERS-1/2 | Space borne | Microwave C/VV/23deg | 25 | 100*100 | 94-06-28 |
| | ’’ | ’’ | ’’ | Route | |
| JERS-1 | Space borne | Microwave L/HH/35deg | 18 | 75*75 | 94-04-22 |
| PHARUS | Air borne | Microwave C/Pol/23deg | 5 | 10*10 | 1997/1999 |
| DTED | - | Raster level-1 | 100/30 | route | 1986 |
| DFAD | - | Vector level-1 | - | route | 1986/91 |
| Map 1:25k | - | Topographical UTM | - | 100*100 | 1990/95 |
| Map 1:100k | - | Topographical UTM | - | Route | 1990/95 |

Table-2: Available data for the Freiburg test area

# 4 DATA PRODUCT GENERATION

## 4.1 DTED Generation

DEM's were generated by automatic optical stereo correlation techniques, using SPOT-Pan imagery and 1:70k aerial photographs. As shown in table-2 three SPOT-Pan images were available. Out of them two combinations could be made. A stereo pair of images acquired at 02-07-94 and 04-08-94, with a short time difference of 1 month and a viewing angle difference of 29.4 degrees. Problem for this dataset was cloud coverage especially around the mountain tops. The other stereo pair contained images 06-08-91 and 04-08-94, so with a time difference of three years, but exactly the same date. The difference in viewing direction is 25.3 degrees and there is no cloud coverage, however during the matching process it turned out that one of the images contains a lot of haze over the city of Freiburg. With the ERDAS Orthomax software DEM's with a 50m grid size could be easily generated within a short time. The obtained accuracy was below the values found in literature, about 20m standard deviation. Besides for a lot of smaller areas manual editing was required in order to remove spikes and other irregularities.
For the correction of the aerial photos a more detailed DEM was required. This was generated out of the aerial photographs, also using the ERDAS Orthomax software. A block of 10 photo's was triangulated, after which for all stereo pairs a DEM was generated with a grid size of 10m. The results of the matching process was better than for the SPOT images, accuracy in the order of 5 m standard deviation and less spikes and irregularities. The individual DEM's were manually corrected for spikes, after which they were used to ortho-correct the individual photos. Finally the individual stereo-pair DEM's were mosaiced to one total DEM of 30*30km.

Conclusion is that in a very short time a moderate accuracy DTED level-1 DEM can be generated out of SPOT imagery. The more accuracy is wished, the more user interaction will be required, which takes time. Also more detailed and higher accuracy DEM's (DTED level-2) can be generated out of aerial photographs. For larger areas this requires more user interaction.

## 4.2 DFAD Actualisation/Generation

By inspection of the available DFAD vector data of the Freiburg area it turned out that the data were old (1986 and 1991) and that the files contained only a limited number of features for most areas (no roads, railways or rivers were included). The data were read in by Arc-Info and combined with the remote sensing raster imagery. For the target area and the area directly around it, the DFAD data were manually actualized and complemented with especially line features. In the neighborhood of the target also buildings and other relevant point features were added, which could be used by the NSF flight simulator for the placement of 3D polygon features. Optical SPOT aerial photo imagery was used providing information on terrain coverage, roads and buildings. Also a classified image was used for the actualization of the terrain coverage area features. For a sub-area fully polarimetric C-band airborne SAR data from PHARUS was used (3m resolution). The different polarimetric channels can be shown in the three color channels so that a colored radar image can be obtained. Using the information in these channels it is possible to perform land use classification, obtaining classes like forest, urban, bare soil, low vegetation and water, which can be shown in thematic maps. These data is also quite suitable for detecting points in the image. The detected points can be used as a pre-selection for finding striking points in the scene.

Figure-7: Original DFAD file projected over an aerial photograph

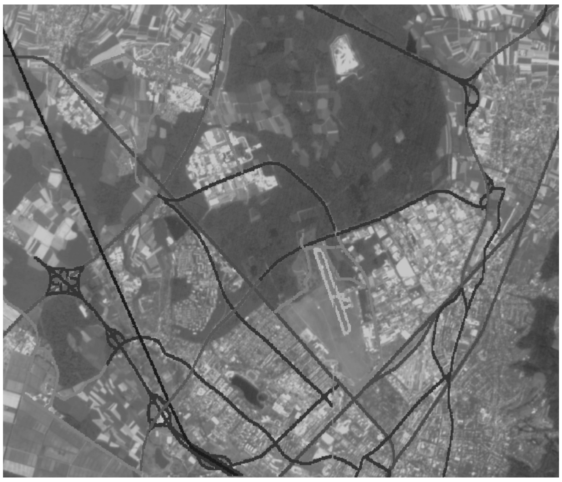

Figure-8: Updated DFAD-file projedted over an aerial photograph

In general it can be concluded that with remote sensing data a sub-selection of the DFAD features can be updated or generated. For area features this can be done quickly using classified imagery. Changes in line features also can be handled easily. Point features are depending much on the resolution of the available imagery. The current process is based on manual editing. Attention should be payed to automization of the process, especially to automatic line following methods. In figure-7 and 8 a part of the DFAD-file is shown before and after editing.

### 4.3 Simulator database generation

For the NSF flight simulator a realistic photo layer for the complete flight trajectory from Volkel to Freiburg was generated. On the border of the city of Freiburg a small airport was defined as target. The resolution of the photo layer was varied starting with 30m for the main trajectory, 10m for the Freiburg region, 2m for the Freiburg city, and finally 1m for the target area itself. In table-3 An overview of the different resolution levels is shown with their source data.

| | Resolution | Area size (km) | Source data |
|---|---|---|---|
| Route | 30m | 80*600 | Landsat TM |
| Freiburg area | 10m | 60*60 | SPOT Pan and XS |
| Freiburg city | 2m | 30*30 | Aerial Phot 1:70k and SPOT XS |
| Target area | 1m | 6*6 | DPA |

Table-3: Generated photo layer resolution levels

For the 30m and 1m resolution levels Landsat-TM and DPA imagery with the required natural color spectral channels were available. So for this imagery only geometric correction, stretching to a realistic color representation and mosaicing was required. The Landsat images were ortho-rectified using gcp’s from 1:100k UTM maps and DTED elevation data. The DPA data only covered a small relatively flat area and were corrected using gcp’s from 1:25k maps and a first order polynom.

For the 10m and 2m resolution levels, higher quality panchromatic imagery and lower quality false color imagery was available. From the false color imagery first a simulated natural color image was generated, which in a second step was merged with the higher resolution panchromatic imagery. In this process it turned out that especially in agricultural areas unnatural brown colors could appear as a consequence of the differences in vegetation coverage between the images. The geometric ortho-correction of the SPOT imagery was done using gcp’s from 1:25k maps and the DTED file. For the aerial photographs first a detailed DEM was generated automatically, after which the individual images were ortho-rectified and mosaiced together. Problems in mosaicing occurred as a consequence of the light fall-off to the edges of the photo-images. Finally smooth transitions between the different resolution levels were generated, by feathering the borders of the images during mosaicing.

The images were transferred to NSF where they were processed by the Evans & Sutherland ESIG-3000 image generation system to a database form suited for near real-time (60Hz) presentation on the outside visual of the simulator during operation. Different combinations of DEM-resolutions, geospecific (photo-layer) detail, geotypical and polygon features were generated. Steering factor in these ingredients is the capacity of the processor, which can handle a maximum number of triangle polygons covered with raster information. At this moment this process of tuning and evaluation of the results with RNLAF test-pilots is still taking place. Clear is already that a combination of geospecific, geotypical rasters and 3D polygon features gives the best performance. For higher flying altitudes (15.000ft) 30m resolution is sufficient, for lower altitudes (300ft) high resolutions of 1m and 3D polygon features are required. In figure-9 An example is shown of a perspective view of Landsat TM imagery of the Rhine Valley.

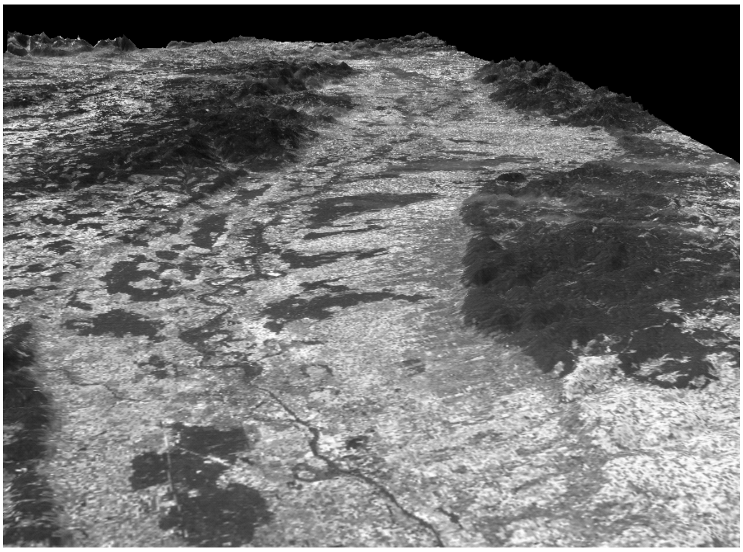

Figure-9: Landsat-TM perspective view of the Rhine Valley (viewing direction south)

### 4.4 Image-map Generation

Objective was the fast generation of map-like products, which can complement or, if no alternative is present, replace the normal used scanned paper maps (electronic maps). In fact a range of different raster products can be distinguished, starting with the natural color ortho-photo-product, via more and more elaborated image-map products (e.g. classified image), finally ending with a raster map. A number of different source image information layers were defined and generated:

- Simulated natural color image, generated out of a false color image;
- Intensity image, generated out of one spectral channel or a combination of spectral channels;
- Radar image, showing relief and radar reflections;
- Shaded relief image, generated from a DEM;
- Classified image with a specified number of requested classes, and represented with a map-like color scheme;
- Vector information, like roads, city names etc, extracted from the image or brought in from other sources;
- Map layout information, like a coordinate frame, north arrow and scale.

In the next step products were defined of combinations of these image information layers. Merging of the different image information layers was done using the RGB to IHS transformation, after which the intensity channels were combined (multiplied or added) followed by a IHS to RGB transformation. This worked well for e.g. the combination of a simulated natural color image with a shaded relief image. For the combination of a classified image with a shaded relief or an intensity image problems with the color scheme can arise. Because of the difference in intensities into the chosen classification colors and the intensity image colors, the resulting colors may deviate a lot from the target map-like colors. For these cases the starting classification colors were adapted with some trial and error. The vector and map layout information could easily be superimposed on top of the image.

Combinations of optical and SAR satellite images were produced: ERS data, which shows the relief quite distinctly, was combined with TM data, resulting in a natural colored cartographic products. Radarsat data with a resolution of about 10 meters was combined with Spot XS data to obtain natural colored cartographic products, which shows relief distinctly and in more detail. Due to the higher resolution more textural information is present, so that such a product also shows more details like roads, buildings etc.

In table-4 the different generated combinations are shown. Most products were generated at two map-scales 1:50k (12.5m pixels) and 1:500k (125m pixels). The results were evaluated by people involved from FELCOP/INDIA and MSS/C.

| Sources image-map product | Sim. Nat. Color | Classified | Radar | Shaded Relief | Intensity | Vector Info. | Map Layout |
|---|---|---|---|---|---|---|---|
| 1 | ● | | | | | | ● |
| 2 | ● | | | ● | | | ● |
| 3 | ● | | | ● | | ● | ● |
| 4 | ● | | ● | | | | ● |
| 5 | | | | | ● | ● | ● |
| 6 | | ● | | | | | ● |
| 7 | | ● | | ● | | | ● |
| 8 | | ● | | ● | | ● | ● |
| 9 | | ● | | ● | ● | | ● |
| 10 | | ● | | ● | ● | ● | ● |

Table-4: Image-map products and image layer sources

Examples of a number of products are shown in figure-13 to 16. In figure-13 a combination of a SPOT-SNC and a shaded relief image is shown. In figure-14 a SPOT Pan image is combined with updated DFAD vector data of roads, railways and waterways. In figure-15 a combined Radarsat and SPOT-XS image is shown. Finally in figure-16 a shaded relief image, SPOT-classified image, and SPOT-Pan intensity image are combined to one map product.

Depending on the objective for which the image should be used preferences for the different products exist. For a fast overview of the area of interest (especially in case of no availability of maps or very old maps) a classified image with some vector information and shaded relief is valuable. For more detailed information and or a realistic impression of the area, in addition to map information, the SNC product is valuable. For a combination of image overview and image detail the classified image combined with intensity may be used. In future further evaluation and tuning of the products will be required. All products can be generated very quickly and almost fully automatically. Only the vector information will take more operator effort and thus time.

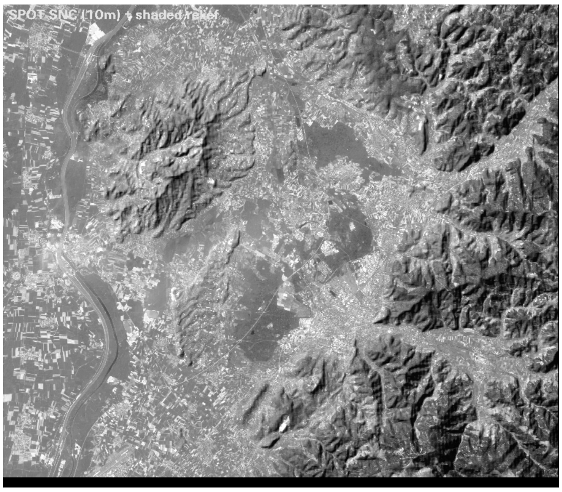

Figure-13: Map product number 3

Figure-14: Map product number 5

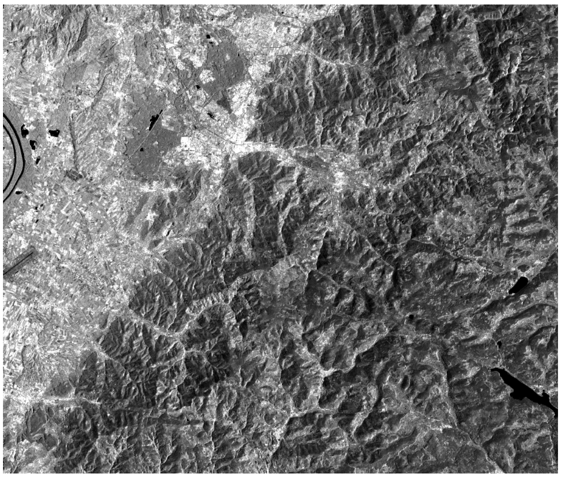

Figure-15: Map product number 4

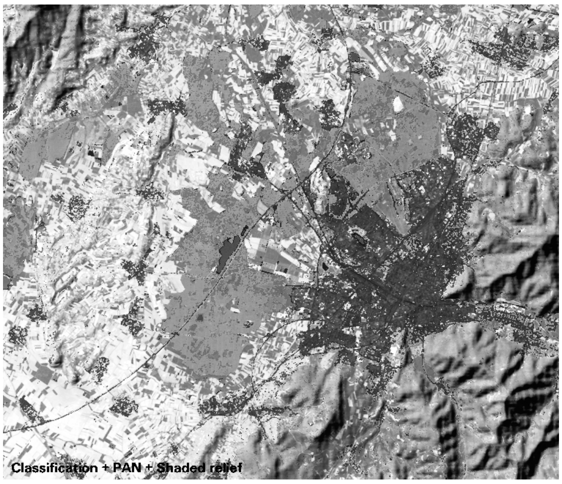

Figure-16: Map product number 9

## 5 EVALUATION AND CONCLUSIONS

Evaluation of the remote sensing products with respect to their relevance for the three military applications will take place in the coming months. At this moment we only can evaluate the products from a remote sensing point of view. In that context it can be concluded that remote sensing can provide relevant geographical information products for all the three applications. These products range from DTED, DFAD files to natural color imagery data and raster map products. Most products can be generated or updated relatively fast, and the required remote sensing source data can be available within a short time and in an independent way. The products can be of value for situations were no alternative products are available at all, even if the quality would be worse than the normally used information. Further the products can be of value for the updating of available imaging information. And finally the information can be of value, because it provides an additional new type of information with which the functionality of the application can be extended.

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