Airborne Multi-Spectral Minefield Survey

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ABSTRACT

The availability of sufficient high quality information on the minefield scenery is an important pre-requisite for the safety and the efficiency of all demining actions. Within the EU project ARC (Airborne Minefield Area Reduction) a system has been developed for airborne minefield survey for use in General Mine Action Assessment, Technical Survey (area reduction and as far a possible mine field delineation), and Post Clearance Quality Control. An important methodological aspect of the selected approach is the pyramidal information structure, which is reflected in the use of satellite data, a helicopter UAV (Camcopter®) and in the developed GIS data base structure, allowing for a hierarchical approach to the information starting from an overview of the situation down to the level of detail required for field work.

The full AGM (Automated Geo-reference Mosaic) makes use of the pyramidal flight pattern. Image correlation techniques are used to geo-reference lower altitude imagery towards higher altitude images. Only the single image on top of the pyramidal flight requires manual geo-rectification. The top image contains sufficient contextual information for the image interpreter to manually assign ground control points. After AGM processing for each individual image the results are stored in GEOTIFF file format, thus preserving the original pixel values and full position accuracy through geo-transformation matrix information.

The ARC Minefield Test trials have been conducted in Croatia during the period of May 12th 2003 till May 23rd 2003.

THE ARC PROJECT

The area affected with antipersonnel land mines in 56 infested countries is estimated to be 1 Mio km², with 60 to 200 million landmines in the ground (Source: Landmine Monitor Report 1999, edited by The International Campaign to Ban Landmines, Human Rights Watch 1999). This represents a serious threat to the human lives and a major obstacle for the development of the polluted region. Humanitarian mine action is of global concern.

A major problem connected with all demining actions is the severe lack of baseline information. To respond to this in a rapid way, cost-efficient data acquisition methods are a key issue.

de Lange, D.-J.; den Breejen, E. (2005) Airborne Multi-Spectral Minefield Survey. In *Advanced Sensory Payloads for UAV* (pp. 18-1 – 18-8). Meeting Proceedings RTO-MP-SET-092, Paper 18. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 MAY 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Airborne Multi-Spectral Minefield Survey	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **TNO Defence, Security and Safety Oude Waalsdorperweg 63 PO BOX 96864 2509 JG The Hague THE NETHERLANDS**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202032., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The ARC objectives are to improve the speed, efficiency, and safety of demining actions by using:

1) High spectral and spatial resolution imaging using a low cost, unmanned, lightweight helicopter drone,
2) Georeferenced image data,
3) combining the image data with other information sources in an advanced Geographical Information System, see figure 1.

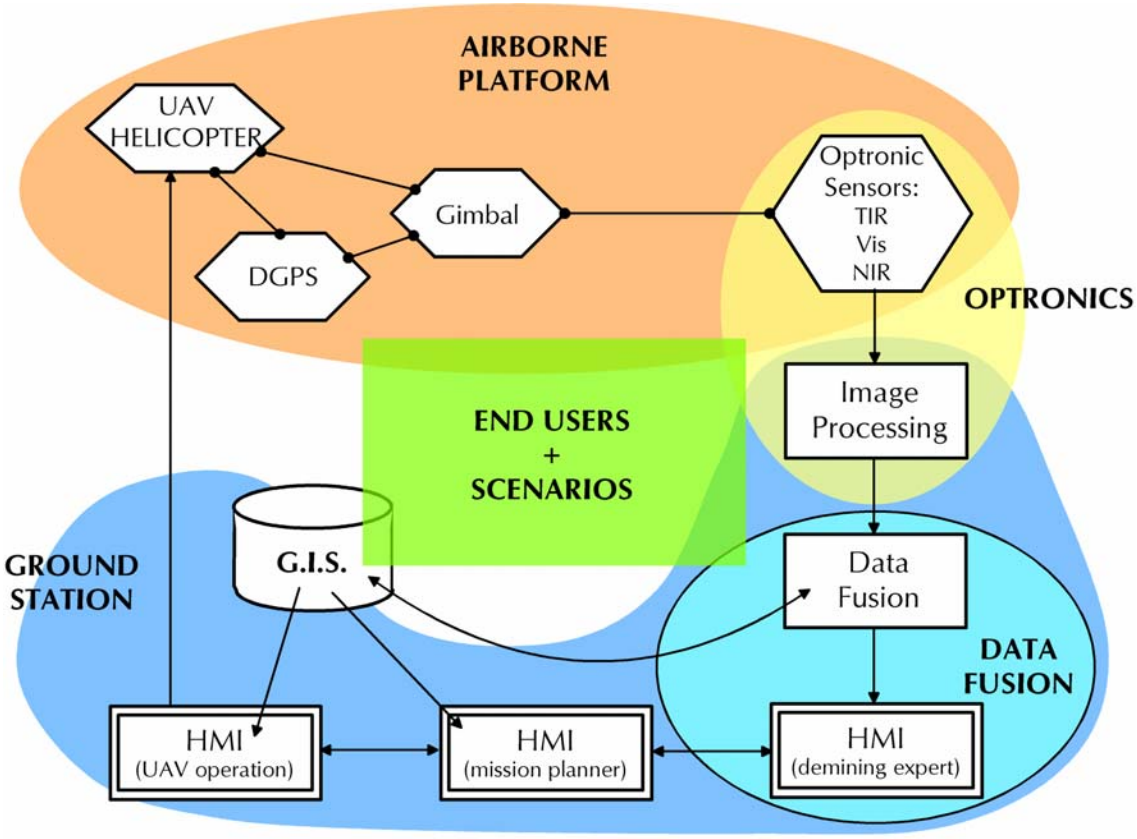

Figure 1: ARC System Overview.

THE ARC SYSTEM

The demining of suspect areas can be improved if more baseline information is available. Usually, the only information of suspect areas are from old maps and visual inspection from a secure road. High resolution imagery from a recent date of the entire suspect area can provide very useful additional information for planning of the demining activity. In the ARC concept imagery at different resolution is gathered, ranging from high level information with imagery at 30 cm resolution up to very detailed imagery at 1 cm resolution. The imagery is recorded from the CAMCOPTER® VTOL-UAV, see figure 2, which is equipped with visual bands, Near-Infrared and Mid-Wave Infrared sensors.

The unmanned mini-helicopter was equipped with an unstabilized gimbal containing a staring multi-spectral electro-optical payload. The high quality images of the 3CCD multi-spectral Duncantech 3100 camera and from FLIR thermal infrared SC3000 QWIP camera were stored onboard. The image acquisition computer was synchronized with the GPS/INS unit aboard the Schiebel CAMCOPTER® UAV helicopter.

Figure 2: The Schiebel Camcopter® with payload mounted (left) and after take-off.

The imagery is only useful if they are geo-referenced in world coordinates, so that information extracted from the imagery can be combined with other information in the Geographical Information System (GIS), like maps, Digital Elevation Maps, satellite images and mine-field records. Manually geo-referencing is a very elaborate task, especially of the many 1-cm resolution images. Furthermore, the small footprint of the low altitude high-resolution imagery often does not show enough manual usable reference points. Within 30 minutes after landing the GPS/INS geo-referencing software was capable to position and present the images, in world coordinates. In the ARC concepts the geo-referencing process is automated as much as possible. Furthermore, automatic image processing algorithms and data-fusion algorithms will help the image-analyst in the feature extraction process. Finally the imagery, extracted features and other data are visualized in the GIS to support demining experts in the minefield survey and delineation.

Pyramidal Approach

Working on different levels of decision imposes different requirements on the level of detail of geo-information and on the area covered by the data, ranging from e.g. national coverage for political decisions to the coverage of individual fields e.g. for field work. Figure 3 gives a schematic view of a hierarchical information model, which takes these different requirements into account.

In the ARC system the pyramidal concept has been implemented by modifying the general view sketched in Figure 3 in a way which logically integrates the different information levels available using state-of-the-art remote sensing tools ranging from (coarser) satellite data to very high resolution (cm range) data acquired from the UAV helicopter.

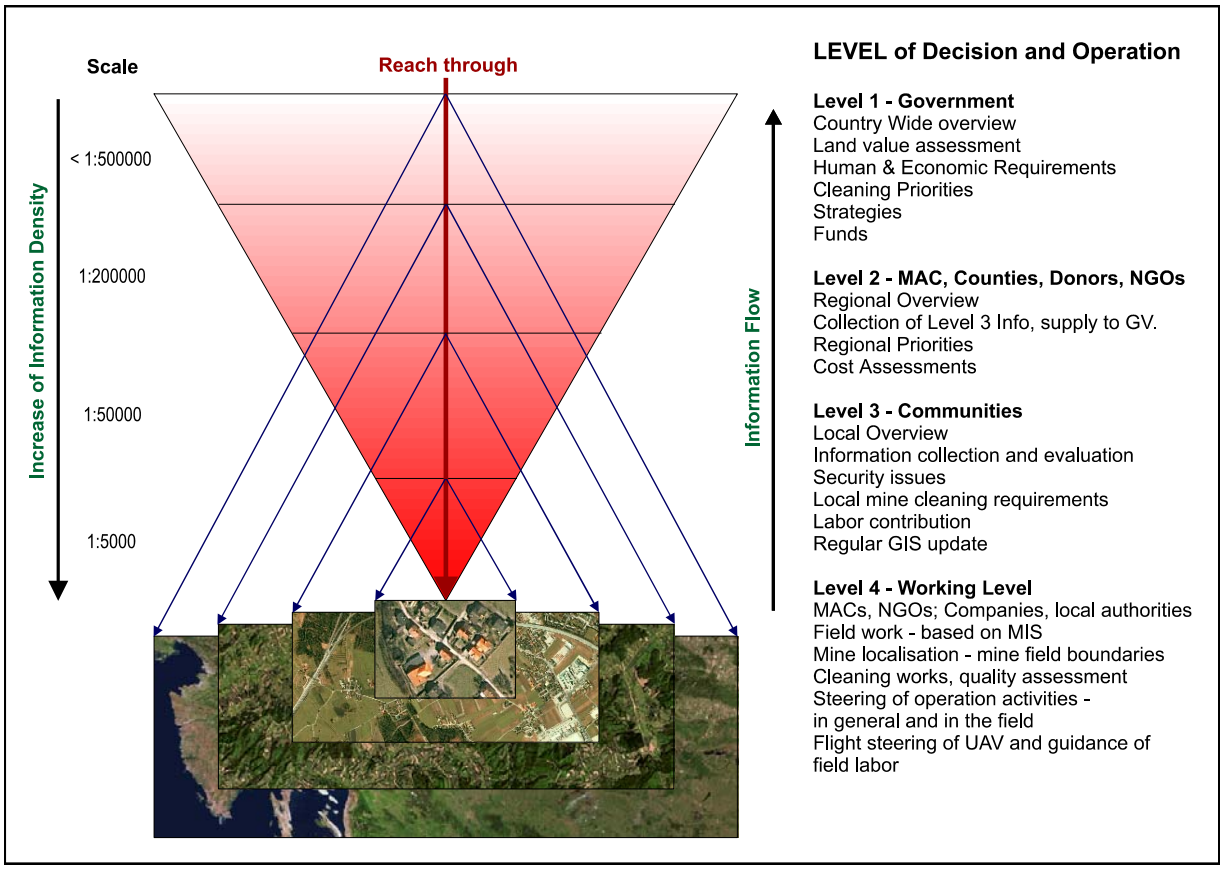

Figure 3: Schematic view of data content and information flow in a pyramidal approach.

ARC Consortium Partners

The ***ARC*** consortium included seven partners from six European countries, covering commercial companies, research institutes and an end-user organisation: CROMAC (Croatian Mine Action Center), FOI (Swedish Defence Research Agency), GEOSPACE (Austria), GTD (Ingenieria de Sistemas y Software Industrial, Spain), IMEC (Ineruniversity MicroElectronic Center, Belgium), Schiebel (Camcopter manufacturer, Austria) and TNO (Netherland's Organisation for Applied Scientific Research).

AUTOMATED GEOREFERENCING MODULE (AGM)

The Automated Georeferencing Module (AGM) is used to provide off-line the geo-referencing information for the *ARC*-images. The AGM is the combination of the inputs from the *ARC* payload (in-flight position and orientation measurements) and an off-line image-processing which enables high precision geo-coding (geo-referencing) of the *ARC*.

The objective of the AGM co-registration is to improve the position accuracy of the geo-referenced images.

The AGM method is based on the Top-Down (multiscale/different flight heights) approach of *ARC*. A manually geo-referenced image of the full surveyed area will be used as a reference-image. This image will be acquired at high altitude. For each acquired image recorded at a lower altitude, the geo-referencing will be made in three steps. First a rough indication of the location will be estimated from the GPS and INS data of the Camcopter. Secondly, this estimate will be refined (made more accurate) by comparing the

acquired image to the reference-image, using an image correlation technique, and determine the relative position of the acquired image within the reference-image in image-coordinates. The third step estimates the world-coordinates by combining the estimated relative position of the image with respect to the reference-image, and the world co-ordinates of the reference-image, keeping the original pixel values and updating only the geotiff transformation matrix.

The information about the world co-ordinates will be used for two different applications:

1) Provide position information of features detected by the image-analysis algorithms. The position information will be used to store the feature the GIS and hence used in the data-fusion process.
2) Provide geo-referenced images and mosaics to the GIS for visual interpretation.

The image correlation is used on image pairs. These image pairs are selected based on their overlap and altitude. The following image pairs are considered: (900m, 900m), (900m, 300m), (300m, 100m), (100m, 30m).

AGM registers multiple images together creating a mosaic in the same coordinate system. It does so by finding the relative translation, orientation and scale change between two images that have some overlap in the recorded area. One can build a mosaic using the relative coordinate system transformations as found by the AGM image registration module.

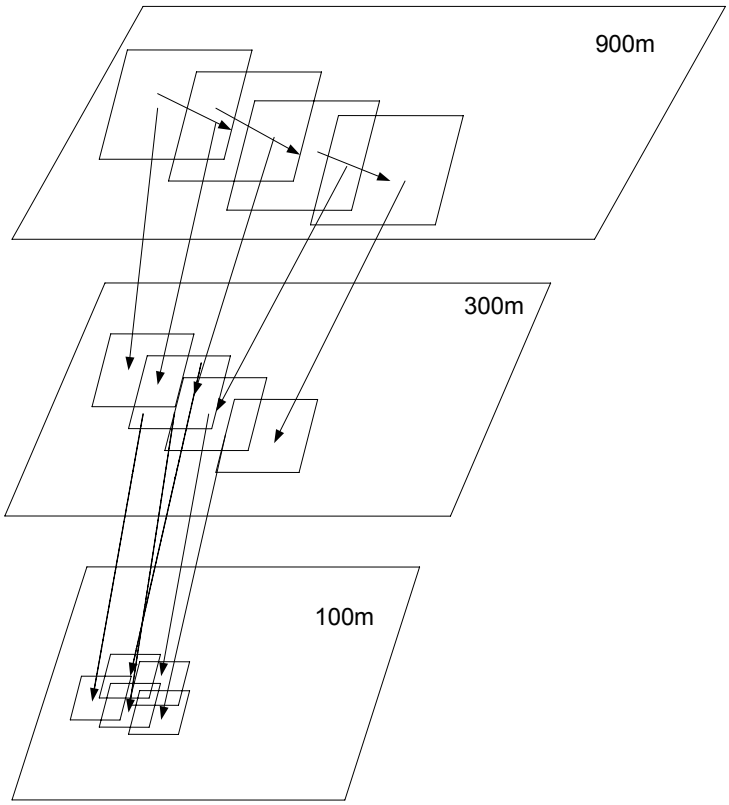

**Figure 4: Pyramid of images at three different altitudes.
The arrows show the direction of the image-correlation.**

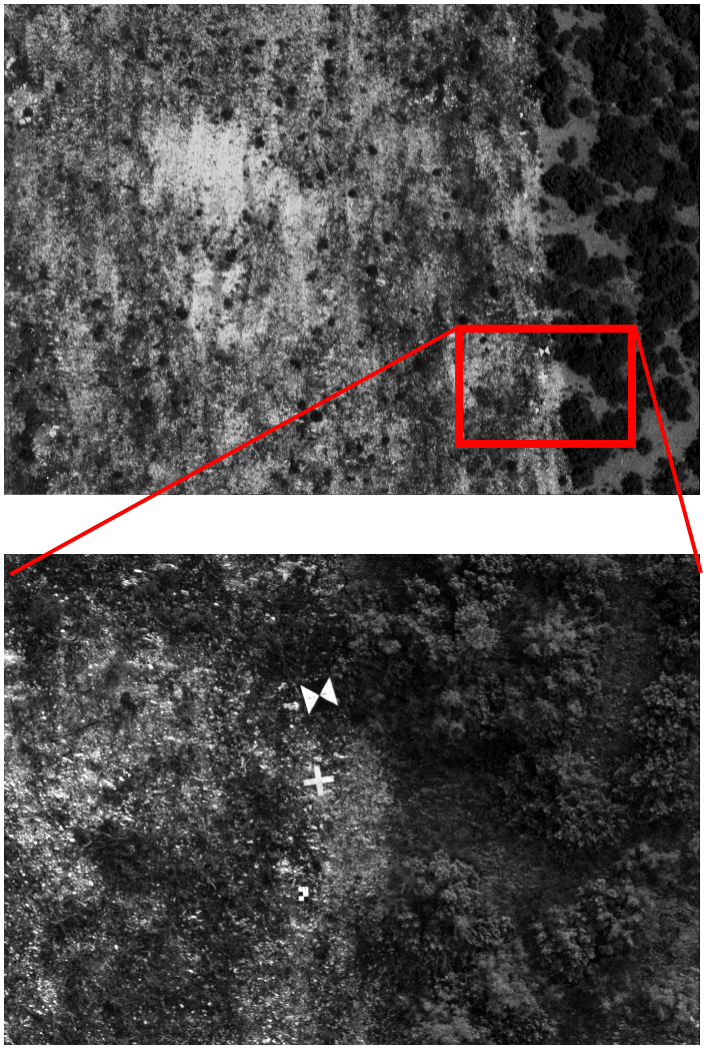

Figure 5: Example of image pair at different altitude, which are used in the image-correlation process.

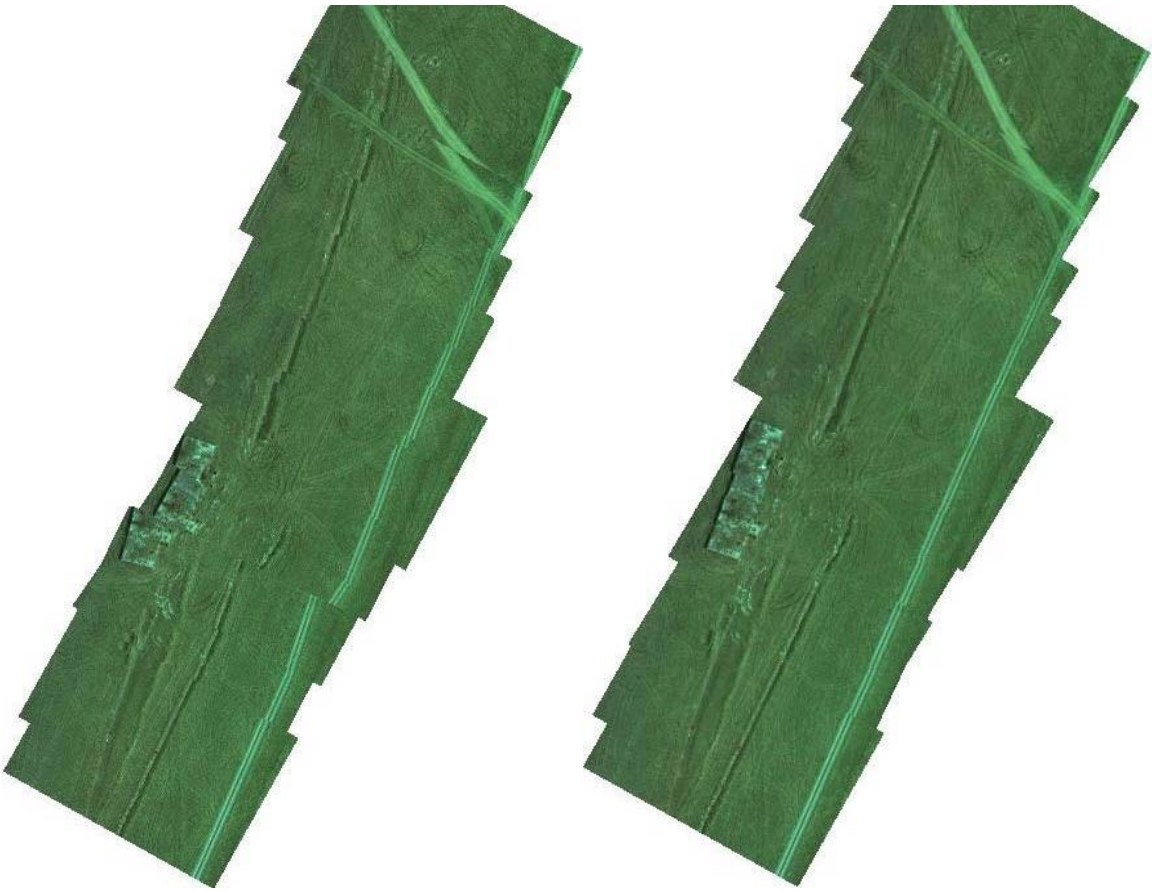

Figure 6: Mosiac of Duncantech images based on GPS/INS information (left) images after automatic geo-referencing by AGM (right) . The mosaics show a bunker, trenches and roads in a grassland.

AGM Evaluation

Manual geo-referencing of the high-altitude mosaic (900m) improved the GPS/INS position accuracy a factor 10 from 17 meters to 1.7 meters.

Using the Automatic Geo-referencing Module (AGM) on the lower altitude images improved the relative position accuracy of the lower altitude (300, 100m and 30m) images with respect to the high-altitude image by a factor 2 – 3.

During the Mine-Field Tests in Croatia 2003 about 10.000 images were recorded during 12 flights. Two high-altitude mosaics were geo-referenced by hand. These mosaics were used by AGM for the automatic geo-referencing of each of the 10.000 images.

Image Interpretation/Image Analysis

After geo-referencing, the images can be used for image interpretation. In the ARC-concept the image analysis is performed by both a human interpreter and by automatic feature extraction algorithms. Figure 7 shows examples of automatically extracted features in the geo-referenced images. All images and extracted features were stored in the GIS, where a data-fusion module could combine the features and extract classification, like used-areas, military active areas, and probably-mined areas. The GIS is used to store and visualize all images, maps, image analysis and interpretation results.

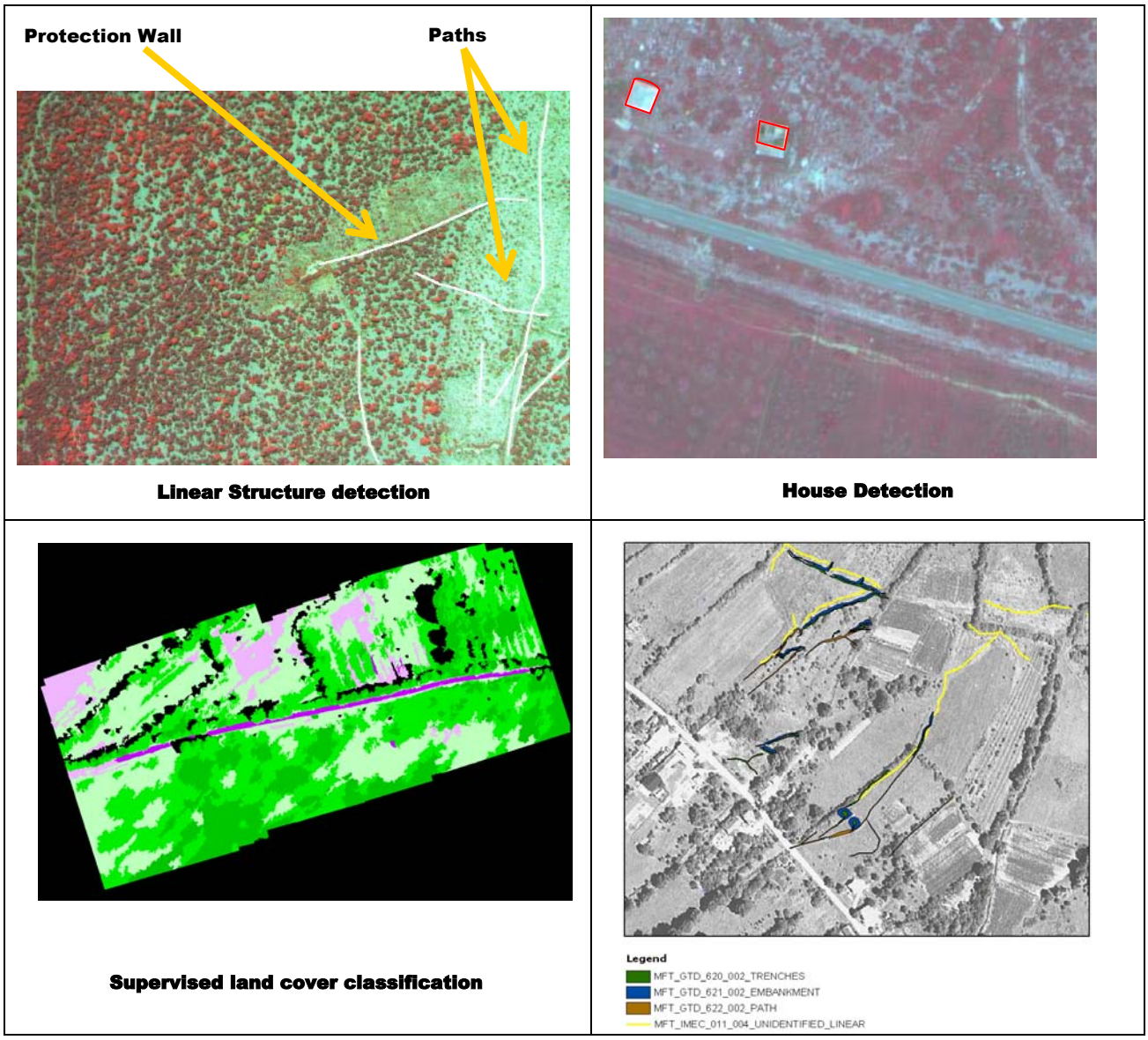

Figure 7: examples of automatically extracted features from geo-referenced images.

CONCLUSIONS

Within the ARC project an Airborne Multi-spectral Minefield Survey System was developed, build, integrated and tested in a mine afflicted area in Croatia. The full chain from mission planning, mission execution, data-acquisition, automatic image geo-referencing, feature extraction, GIS-integration, data-fusion and data-visualization was implemented.

For the data analysis all extracted features must be overlaid in the GIS in world-coordinates. Normally all geo-referencing is done by hand, which takes a lot of time. The use of an automatic georeferencing module (AGM) speeds up the process significantly. For a typical pyramid flight of 800 images only 1 image needs to be geo-referenced by hand, the other 799 images are handled automatically by AGM.

ACKNOWLEDGEMENTS

The ARC project is sponsored by the European Commission as project IST-2000-25300.