



**INTERNATIONAL TRUST FUND**  
*for Demining and Mine Victims Assistance*

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Ltd.



Deployment of the Decision Support System for Mine Suspected Area Reduction in Bosnia and Herzegovina

M. Bajić, Č. Matić, A. Krtalić, Z. Čanđar, D. Vuletić

# RESEARCH OF THE MINE SUSPECTED AREA



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## EDITOR'S NOTES

This publication presents methodology for application of the *Advanced Intelligence Decision Support System (AI DSS)* for the assessment of the mine suspected area in the frame of the humanitarian mine action. Besides the methodology, the publication contains instructions, explanation and examples. Its aim is to enable humanitarian mine action experts in the Mine Action Centres (MAC) or Governmental Administration to prepare conditions and to apply AI DSS technology in their country. It can be useful to scientists who research the landmine problem too. Earlier version of similar publication was limited to the analysis of the data contained in the MACs and its usage was restricted only to MAC and to team who applied AI DSS technology. The presented methodology is the outcome of the long-term international scientific cooperation of the researchers, mainly members of Scientific Council of Croatian mine action centre (CROMAC) and Centre for testing, development and training Ltd., with experts for operations from CROMAC on FP6 European Commission projects "Space and airborne Mined Area Reduction Tools (SMART)", IST-2000-25044, "Airborne Minefield Area ReduCtion (ARC)", IST-2000-25300 and other [1], [2], [12]. In the projects SMART, ARC, [1], [2] and [12] are used aerial multisensor images, the ground truth missions are important part of activities [3], [5], the contextual information gathers [4], [1], [2], [12], the formalized expert knowledge, [6], [7], [8], [1], [2], [12] is introduced. While detection of landmines from air is not feasible yet (except in the simplified idealized conditions) the carrier of the information about mine situation is introduced and named indicator of mine field presence (IMP) and the indicator of mine field absence (IMA) [8], [2], [12], [6], [7]. First analytic documents [9], [10] were introduced in 2002. The first reconstruction in office (reconstruction on paper) of the polygons of the minefields were introduced in [9], [10] starting from mine field records. There were introduced separation lines, zones; the history is included in the procedures. The important advancement started in 2005, when the statistical analysis of the mine field records was applied [11]. Besides the analytic assessment of the mine suspected area, the explicit sets of general and particular requirements on the acquisition of the aerial multisensor images become standard practice in [1], [2], [12].

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# INTRODUCTION

The advanced intelligence technology was developed and deployed into operations of humanitarian mine action in 2008/2009. Its aim is to support decisions making about the mine suspected area, and is introduced and explained in the chapter one. The aim of this original technology is to enable reliable assessment of the mine suspected area (MSA), propose areas that could be excluded from the suspected area, define areas that are suspected but never have been considered as suspected, all this without deminers' entering into the mine suspected area. The entering into the mine suspected area is hazardous and very costly and this is reason to introduce advanced intelligence technology mainly based on the usage of the aerial and space borne images, being sources of new data and new information. The summary of the military doctrine regarding the landmine – minefields use for protection of the forces, objects and the terrain is presented in chapter two. This text is enriched with very valuable original examples, which show and describe the possible situation of the former zone where the warring units were deployed. The user can find there the generic answers about the deployment of the landmines and the mine fields, all in correlation with the former units' deployment. Besides the mentioned examples, there are given realistic models for analysis of the former situation based on the information that is available in the mine information system (MIS), military maps and memoirs (incomplete and imperfect although the only available). The numerous images show the objects of the former separation or the battle zone, being seen from the ground in 2010, this enables user to imagine how these objects were looking before. The analytic assessment of the mine suspected area based on described background is considered in third chapter. It contains all findings that are possible without entering into mine suspected area. In any considered case, the analytic assessment is finalized with the general and specific requirements for the airborne and space borne collecting and producing new, additional data, information and evidences about the former situation. In simplified interpretation, the general and specific requirements are the wish list, while they are based on available information and data in mine action centre (MAC) that are incomplete and imperfect. In the same time the general and specific requirements have all characteristics of the hypotheses, although were not formalised in this manner. The chapters two and three are presented in verbal form, without quantitative measures. The chapters four, five and six very shortly outline the quantitative spatial analysis of the considered scene, planning and doing the aerial missions, processing and interpretation of the collected images and other data. The chapter seven considers the formalizing the experts' knowledge and the contextual data and information. The chapter eight considers the fusion and the production of the outputs. Follow conclusions and references.





# 1. THE ADVANCED INTELLIGENCE TECHNOLOGY FOR SUPPORT DECISION MAKING ABOUT THE MINE SUSPECTED AREA

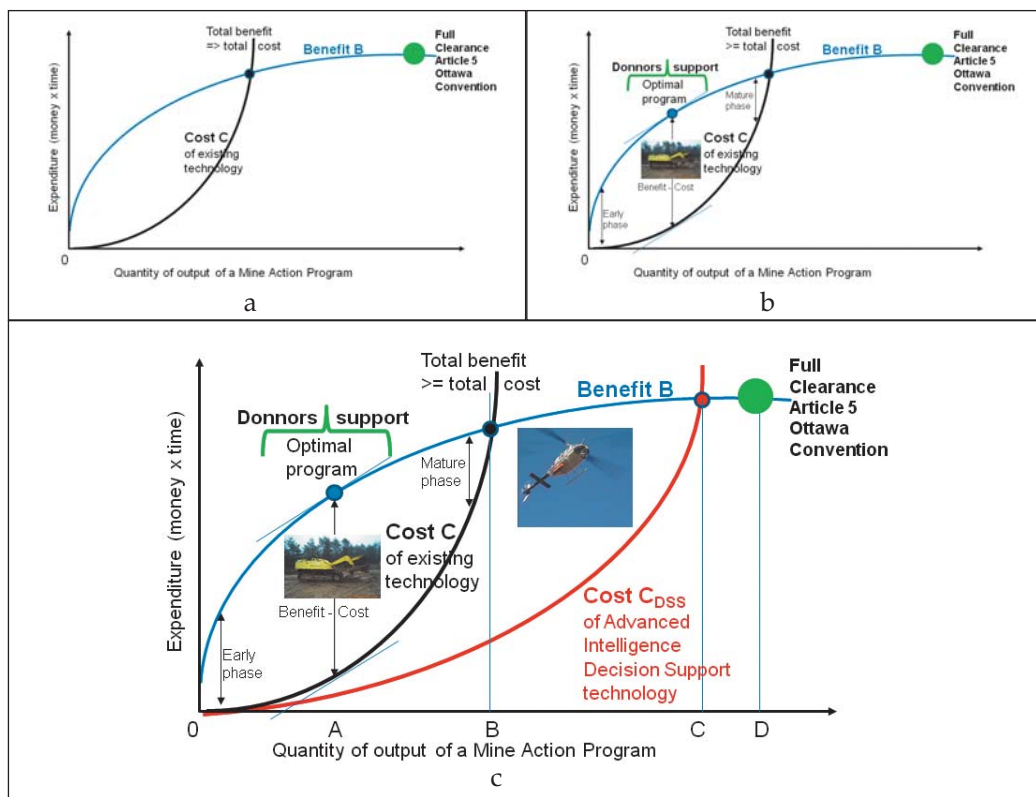
There were several R&D projects about the potential application of the airborne and space borne remote sensing for the mine action which never become really operational. Nevertheless, they provided the background for the success of the Advanced Intelligence Decision Support System (AI DSS). The AI DSS is the first solution based on the airborne and space borne remote sensing for mine suspected area assessment that was implemented into the operations and achieved operational success in Croatia, Bosnia and Herzegovina (Bajić & Turšič, 2010). The AI DSS was developed and operationally implemented by Faculty of Geodesy University of Zagreb, HCR Centre for Testing, Development and Training Ltd., Zagreb, Croatia, starting from the generic methodology of SMART (EC IST-2000-25044) and own development and advancement, supported by Croatian Ministry of Science (Fiedler et al., 2008.). The AI DSS combines (Bajić, 2010):

- a) Analytic assessments and derivation the Statements of Operational Needs about the availability and quality of the data and information in the Mine Information System (MIS) and geographic information system (GIS) of the MAC.
- b) Airborne multi sensor imagery acquisition and usage of satellite imagery that provide new data, information and evidences about the MSA state (the indicators of mine presence and mine absence) with high accuracy and confidence.
- c) The multilevel fusion and multi-criteria, multi-objective processing, interpretation and production of outputs.

The application of AI DSS starts with information and data about the area where mine fields were deployed many years before (e.g. 1991 - 1995 in Croatia, 1992-1995 in Bosnia and Herzegovina). The data and information available in the mine action centres about the contamination with landmines are incomplete and imperfect (although they are the only and the best source about the considered problem). Therefore the mine action centres continuously do surveys and additionally collect missing information and data by all means. The several yearly revisions are ordinary practice in the mine action centres until the additional changes became small. The advanced intelligence technology uses new sources of information and data (airborne and space borne multisensor images) and provides evidences about the former situation in the mine suspected area. The processing and interpretation of the multisensor images enable to reconstruct on the maps the spatial distribution of the units which deployed the mine fields. The remains of the engineers' objects, supported by the data and information about time – space changes are the main source for the considered purpose. In the AI DSS technology is applied set of the military intelligence categories: planning and direction, collection, processing and exploitation, analysis and production, dissemination and integration, evaluation and feedback. The targets of interest are remains of the objects which have been military ones many years ago; therefore the AI DSS technology has also certain features of the archaeology.

The projects in Croatia and Bosnia and Herzegovina were initiated by International Trust Fund for Demining and Mine Victims Assistance (ITF), Slovenia, and supported by US Department of State Bureau of Political-Military Affairs Office of Weapons Removal and Abatement. The application of the AI DSS enabled CROMAC to exclude 28 km<sup>2</sup> from

MSA (56 km<sup>2</sup>) and include 6 km<sup>2</sup> to MSA in community Gospić (Bajic et al., 2009). The ratio of cost of CROMAC's conventional technology to the cost of AI DSS technology for Gospić was 80:1 (for another community this ratio will reach 141:1). Important contribution to the development of AI DSS has been provided by Croatian mine action centre (CROMAC), by continuous operational support, data, information and expertise in mine action. Working in these two projects we became aware that AI DSS has wider potential for the mine action and could play more important role than was expected (Bajić & Turšič, 2010), (Bajić, 2010). The AI DSS supports achievement of the goal of Ottawa Convention<sup>1</sup> Article 5, that is to remediate all land contaminated by landmines in ten years after the signature the Convention. The development of the mine action program, shown on Fig. 1.1., explains the problems to achieve this goal. The cost of the mine action program

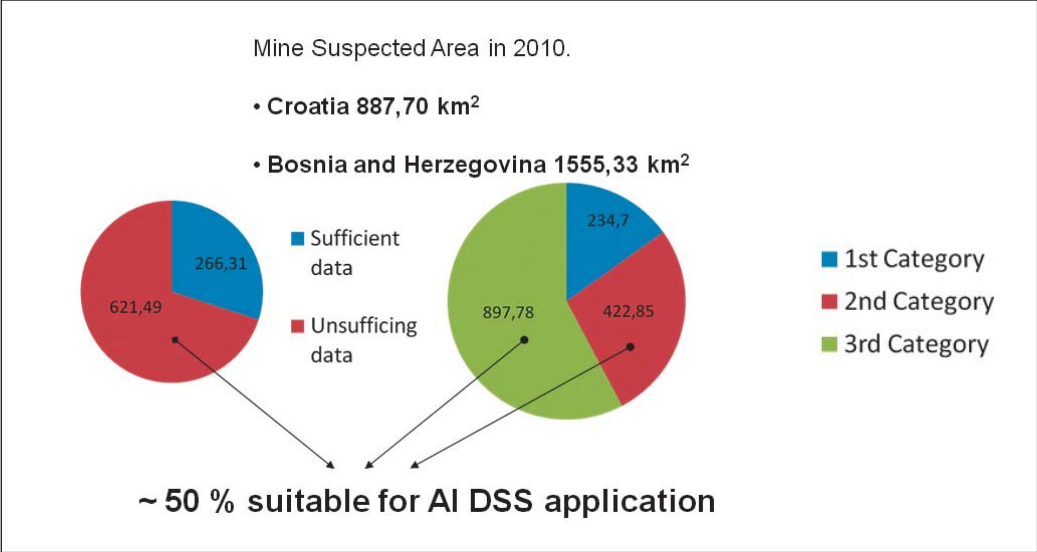


**Figure 1.1.** A convergence to the goal of Ottawa Convention Article 5. a) Cost of the demining program increases monotonically with the amount of its output, and after certain level a total benefit and total cost become equal (B). b) Donors support optimal program (A), where the ratio of the benefit and the cost has a maximum. c) The existing mine action technology can not provide achievement of the goal of the Article 5 of Ottawa Convention for ban landmines in acceptable time duration. The application of the AI DSS technology due to its cost and capacity can shift quantity of the mine action program very near to the goal of the Article 5 Ottawa Convention. Derived on basis of (Keeley, 2005).

<sup>1</sup>The Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction.

increases with increase of its output, after certain stage the cost of the program equals to and grows up from the benefit of the remediated area Fig.1.1a. The best ratio of the benefit to cost of the used technology is preferred and supported by donors, Fig. 1.1b. The most efficient available demining technology can not achieve the goal of Ottawa Convention Article 5 in the ten years time, to remediate all suspected area. The cost of the AI DSS is nearly 100 times lower than the cost of the available technology, in the same time its capacity is significantly larger and it is not labour intensive. By this features the AI DSS technology can shift the cost from position B to new position C, near to position D, Fig. 1.1c.

The benefits of the application of the AI DSS technology will be considered on the data from Croatia and Bosnia and Herzegovina, Fig. 1.2 and Fig. 1.3. In accordance to the experience in both countries, the AI DSS technology is the most efficient in the regions covered by forests, in hilly and mountainous terrain where demining machines can't be used. The additional issue is lack of the information and data for clearing and search operations. In Croatia this is category with insufficient data, in Bosnia and Herzegovina it is second and third category of the terrain, Fig.1.2.

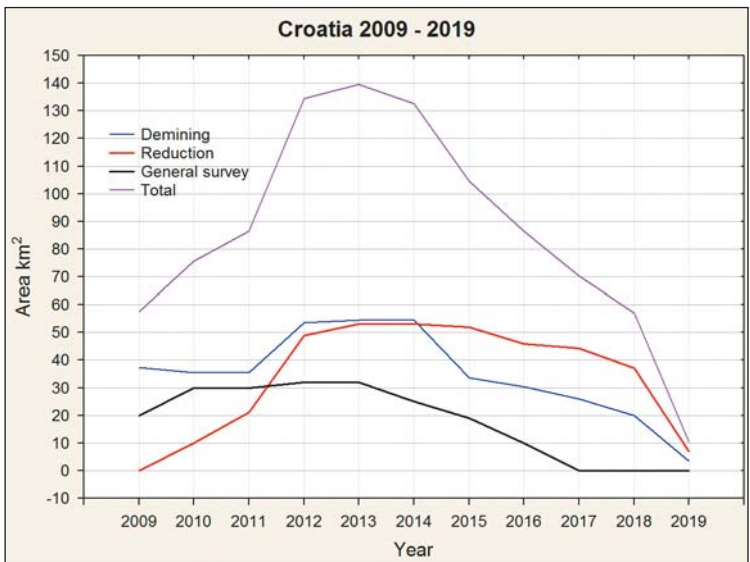


**Figure 1.2** The magnitude of the mine suspected area in Croatia and Bosnia and Herzegovina where is possible remediation of the mine suspected area by the AI DSS technology.

There are nearly 300 km<sup>2</sup> in Croatia and 700 km<sup>2</sup> in Bosnia and Herzegovina where the AI DSS technology can be applied and where remediation of the mine suspected area is guaranteed. The main limitation of the AI DSS technology is requirement that trees are without leaves and mountains shall be without snow in the time of the aerial acquisition. Depending on kind of the terrain, there are available only spring time months for aerial images acquisition, from February to May. If the meteorological conditions are suitable for flights and the visibility for imagery acquisition, the acquisition over 300 km<sup>2</sup> in Croatia

can be realized in two – three weeks. In Bosnia and Herzegovina the imagery acquisition over 700 km<sup>2</sup> can be realized in six to eight weeks. It is important to note that remains of the war at the mine suspected area decrease their usability by time and that each lost year can not be compensated later. Therefore we do intercede for aerial acquisition as soon as possible in both countries.






The temporal dimension of the benefit which can be achieved by application of the AI DSS technology is considered in relation to Croatian strategy for period 2009 to 2019 (CROMAC, 2009), Fig. 1.3. If the aerial images acquisition could be done in spring 2012, in 2012 and 2013 can be expected significant remediation of the considered 300 km<sup>2</sup>, in the categories „reduction” and „general survey”, Fig. 1.3. The additional positive consequence could be earlier finishing of these two categories.



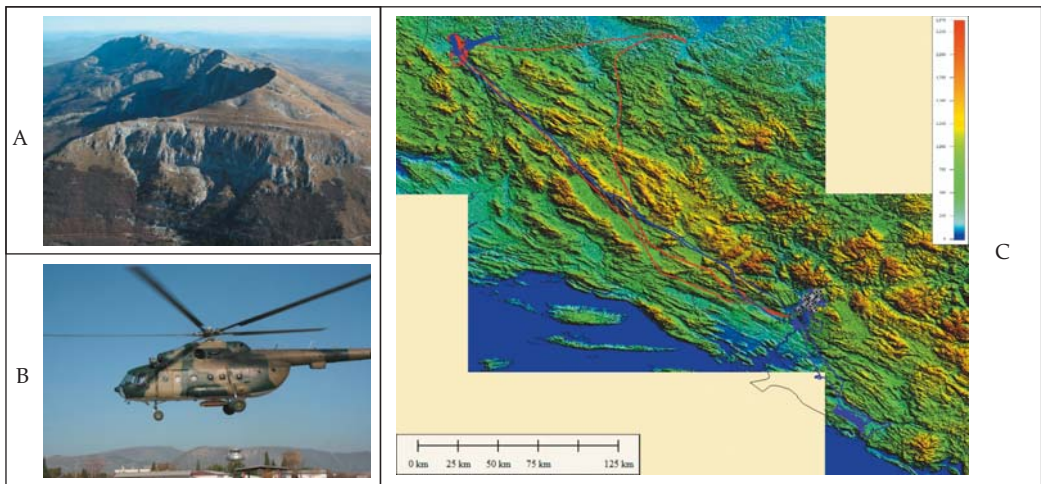
**Figure 1.3** The main features of a mine action program in Croatia, for period from 2009 to 2019.

The methodology of the AI DSS has its roots in the EU project SMART (Yvinec et al., 2008), but only support of Croatian Ministry of science enabled to build up the aerial multisensor images acquisition system and integrate it into operational technology, Fig. 1.4, (Fiedler et al., 2008), (Bajić et al., 2008). The critical overview of the contribution to the mine action, of the projects noted at Fig. 1.4 can be found in (Bajić & Gold & Božičković, 2008). The initial aerial multisensor images acquisition system was developed in 2001-2002, based on helicopter Bell-206 aerial platform, which has endurance 2:15 h, (Bajic, 2003). The aerial missions over the mine suspected areas require longer endurance and the helicopter Mi-8 was used as more suitable aerial platform, its endurance is 4:30 h, Fig. 1.5. Technology of the Advanced Intelligence Decision Support System become fully operational in 2008, continued in 2009 and 2010. Mine action centres in Croatia and in Bosnia and Herzegovina select mostly the mountainous and forested terrains for application of the AI DSS. The cooperation with air forces of Croatia and with air forces of Federation

Bosnia and Herzegovina which provide aerial platforms and skilled pilots was excellent and contributed a lot to success of the aerial acquisition missions.

<p><i>Airborne mine field detection: Pilot project Mozambique, 1996-1999.</i></p>	
<p><i>MineSeeker, Kosovo, 2000-2001.</i></p>	
<p><i>Airborne Minefield Area ReduCtion (ARC), IST-2000-25300, 2001-2004.</i></p>	
<p><i>Space and airborne Mined Area Reduction Tools (SMART), IST-2000-25044, 2001-2005.</i></p>	
<p>System for the multisensor airborne reconnaissance and surveillance in crises situations and protection of environment, project TP-006/0007-01, support of Croatian Ministry of Science, Education and Sports, 2007-2008.</p>	

**Figure 1.4** The research of the aerial and space based remote sensing technology aimed to support mine suspected area reduction started with ill posed goal „detect anti personal landmines from air“. After several phases was obtained the decision support system for the assessment of the mine suspected area.



**Figure 1.5.** Examples from aerial missions. A) Mine suspected area at the mountain Velež, near Mostar in Herzegovina. B) The helicopter Mi-8 in flight, with sensors' pod (orange colour) installed underneath the fuselage. C) Three different types of the mine suspected areas in Bosnia and Herzegovina where AI DSS technology was applied (2009 – 2011).

Besides the acquisition of the aerial multisensor images, the use of the satellite images is important source for the AI DSS. The use of the satellite images was introduced for AI DSS project in Bosnia and Herzegovina (Bajić & Turšič, 2010) by additional support of the International Trust Fund for Demining and Mine Victims Assistance (ITF), Slovenia.

The main pillars of the AI DSS technology are shown at Fig. 1.6. In the whole process of the application of the AI DSS technology, the mine action centre (MAC) has the main role.

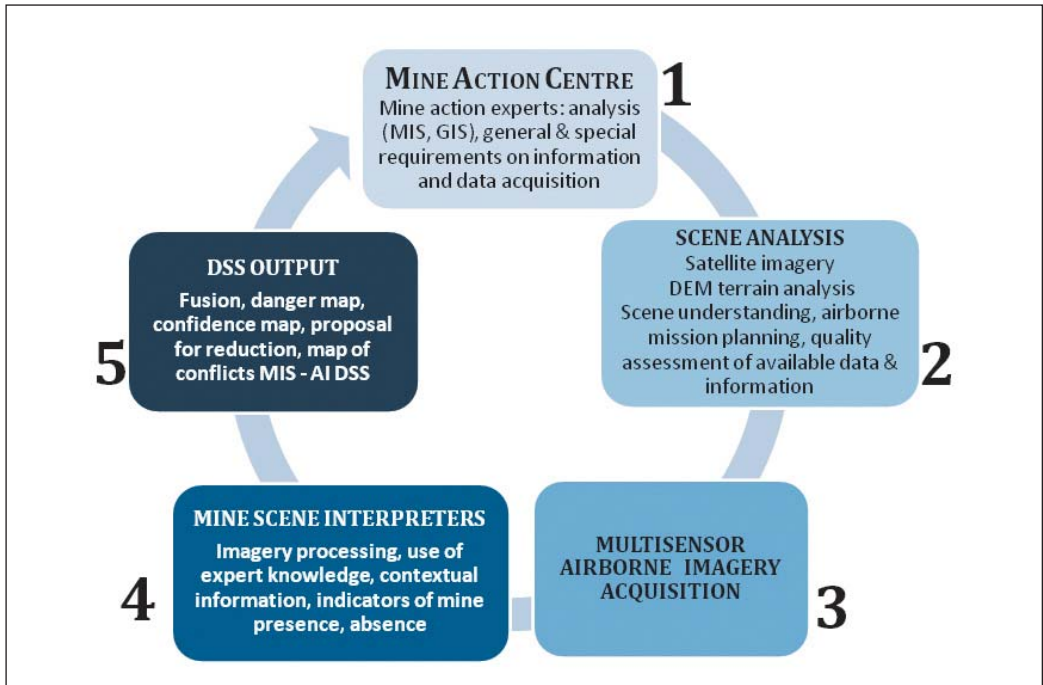


Figure 1.6 The main pillars of the AI DSS technology.

At the beginning, the mine action centre selects areas where AI DSS technology should be applied (e.g. the conifer forests (evergreens) are excluded). The mine action experts provide data from the mine information system (MIS) and the geographic information system (GIS), make analysis of quality of both, they derive general & special requirements about missing information and data. This is the first input for the planning of the aerial acquisition missions. Set of these functionalities is not standard for mine action centres and we have derived standard operational procedures for the mentioned tasks. The duration of this phase is the longest in comparison to the other phases from Fig. 1.6, and the most unreliable for planning. Experience from Croatia and from Bosnia and Herzegovina tells us that this is from six to more than nine months. The data available in central MIS and GIS of the mine action centre are harmonized and made uniform regarding the geographic coordinate system, projection, digital ortho photo maps are compressed and the radiometric information is lost. In regional offices exist and are usually available raw data, with more details and sometimes with more suitable projection.

The scene analysis starts after the acceptance of the mine suspected areas for application of AI DSS technology. The mined scene interpreters (members of the AI DSS team) start analysis and the familiarization with terrain, mine suspected area data, contextual information. For this purpose, satellite scenes (multispectral and panchromatic) of the satellites Ikonos, QuickBird, WorldView1 (and hopefully of WorldView2) are intensively used. The analysis of the slopes based on the digital elevation terrain provides evidences about accessibility on the mountainous terrain; analysis of the water coverage enables assessment

of the mine suspected area in swamps. The participation of the experts for mine action from regional offices (responsible for the considered mine suspected area) was approved as very important and crucial. The planning of the aerial acquisition mission is a simple task, once all features of the mine suspected area and terrain were known in details. This phase requires several months to enable the full understanding of the scene, can be done in the frame of three to six months (depends on the delivery of the satellite images).

The aerial multisensor imagery sensor system is selected upon the requirements about the targets that should be detected and the missions are realised by following team:

- a) pilot, co-pilot, aircraft's technician,
- b) mission leader, navigator for the acquisition mission,
- c) operator of the sensors, assistant operator,
- d) technician for sensors, acquisition units, for power supplies.

The processing and the interpretation of aerial and satellite images together with all other kinds of data and information are the functions of the mined scene interpreters. Imagery processing, geocoding, use of expert knowledge and the contextual information, detection of the indicators of mine presence (IMP) and the indicators of the mine absence (IMA) are examples of the whole process. The aerial multisensor images the satellite images provide new evidences about the indicators of a mine presence and of mine absence.

The next phase of the AI DSS technology process is the fusion of all data, calculating and production of the maps of the danger, the map of confidence and the proposal for excluding from the mine suspected area, for change of the category of the mine suspected area and for inclusion in the mine suspected area. There are two additional products, the map of the locations and types of the indicators of the mine presence (IMP) and the indicators of mine absence (IMA). Final product is the map that shows difference of the data obtained by the AI DSS technology and the data that exist in the mine information system (MIS) of the mine action centre.

The final phase of the AI DSS technology application is the delivery of the products to the mine action centre, which is the only authorized entity to accept or not the proposal of the project and to make changes in the mine suspected area documentation. This phase is very important and should be planned and prepared at the beginning of the whole process.





## 2. ANALYTIC DATA PREPARATION

Analytic data preparation is a first phase in the process of mined areas research. Using analytic preparation, a detailed analysis of **mine-explosive obstacles (MEO)** is conducted according to available records on mine-explosives obstacles and with aid of other information, which can be in specified way connected to placement of mine-explosive obstacles.

According to present experiences in humanitarian demining, available MEO records do not show complete and precise information on MEO, and analytic activities must be directed to research of other information and/or instances, which initiate presence of mine-explosive obstacles.

Other than analysis of MEO records, and the original information on mining, analytic data preparation encompasses also data analysis on military mining, data on mine incidents, data on found mines and mines' explosions, humanitarian demining results, technical survey results, military maps, terrain characteristics, collected data and information from members of military units, local population, released publications on war military activities and other sources.

It is necessary to investigate, by analysis of available data, in all details a data content and possibilities of their application in study of mine-explosives organisation in concrete war conditions. Hence, in analytic preparation phase, all kinds of available data are primarily put in function of detection of mined areas, in order to achieve strong background for further activities relating to assessment of mining state and collection of new data.

Analytic work encompasses a number of reciprocally conditioned procedures in studying available data and instances, analysis, comparison, systematisation and their gradual integration in reconstruction integer of mine-explosives obstacles.

Following data analysis, it is necessary to create logical and related data groups, which will ease their understanding, linking and positioning on the ground.

In research work, it is very important to determine qualification of data in accordance to warring parties and their units, chronology of military activities, and movement of defence lines with placing mine-explosive obstacles.

Experiences from Croatian Independence War (Domovinski rat – Fatherland War) show frequent cases of line movements, which led to “overlapping” of old and new defence positions or occupation of old position from the other war party. This complicates mine situation and requires a serious analytic work.

It is necessary to create, through analytic data preparation, databases of uniform data that will ease research work by functional correlating of all available data.

Hence, it is necessary to create appropriate tables for input of analytic data that will give relevant information in research procedures. Also, for analytic work, it is necessary to own adequate cartographic bases, which will enable collection of geo-spatial data and precise import of available data.

It is necessary to use symbols, colours, hatching and other fonts in data presentation on cartographic base, in order to provide clarity of data, to perceive functional linking and reciprocal data relations.

The results of analytic preparation are used for assessment of mined areas; approximate borders of mine suspected areas and other relevant indicators on **mine suspected areas (MSA)** state. According to available data, missing data is determined and requirements

are expressed for collection of specified additional information, which are important for clearer definition of MSA.

The results of analytic preparation will greatly depend on expert military knowledge, skills and team dedication in research work.

The procedures of data analysis and data linking are shown through following work overview and they can appear in practice as available data and they are of special importance for research of mine-explosives obstacles.

### 2.1 Analysis of mine- explosives obstacles records

Mine record of the Croatian Army - pic.2.1.1

**DJELOVODNIK MINIRANJA**

MŠ: KIBNIK, GAN - BILJEŽKA: **Miniranje**

1. Događaj (sadržaj) **Miniranje**

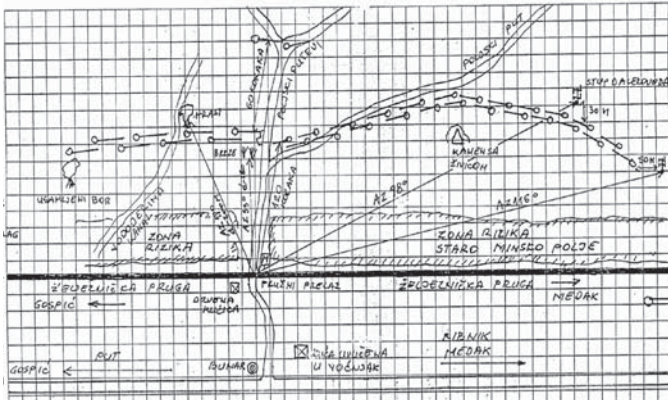
2. Događaj (vrsta) **Miniranje**

3. Događaj (mjesto) **Miniranje**

**Upozorbe:**  
Ovo minsko polje može izmijeniti neprijatelj,  
budi oprezan pri razminiranju!

**SHEMA MINIRANJA**

Razmjera: 1:1000  
1cm = 1m



Mine record of the "Serbian army krajina" - pic.2.1.2

**ZAPISNIK MINSKOEKSPLOZIVNE PREEPRE (MEP)**

Karta: BUBUŠICA, B:1:450000, list br: A-3, koordinata: x:626525, y:670350

Izdavač: 1792, A - PODACI O IZRAZI

Organizaciona jedinica: **1. TA. Z. SREBROVODSTVO/ŠKARINI TIJELU NA KANDOLICI U ČAGLAVIČIMA**

Raspored MEO na razminiranim područjima:

1. MEO	1. SREBROVODSTVO
2. MEO	2. SREBROVODSTVO
3. MEO	3. SREBROVODSTVO
4. MEO	4. SREBROVODSTVO
5. MEO	5. SREBROVODSTVO

1. Vrsta MEO: **PROTUPLOVNI MINSKO EKSPLOZIVNI MINSKO POLJE**

2. Broj reduca (sadržaj) u MEO: **10**

3. Broj reduca (vrsta) u MEO: **10**

4. Podaci o godišnjem razminiranju: **1992.**

Datum izdavanja: **17. 11. 92.**

The records of mine-explosive obstacles (records of MEO) are the original documents on fabricated (or placed) mine-explosive obstacles (or MEO).

Based on MEO records, mine-explosive obstacles are removed (or demined) when they are not anymore required, and especially after a war conflict.

In humanitarian demining activities MEO records are the primary documents for definition of mined areas and buildings, and state of MSA as a whole.

Practice in humanitarian demining shows that available MEO records do not provide complete and precise information on mine-explosive obstacles in the areas of war military activities.

Records often do not exist for all placed MEO in area or available records do not include precise

information (or there is not any) on location of MEO, type, quantity and lay-out of mines, information on manways, information on reinforcement of available MEO, information on executors and other information on MEO according to concrete situation.

It is, hence, necessary to determine through detailed analysis reliability of available MEO records, missing information, and imprecision in records, and define methods for collection of additional information to improve possibilities of more precise definition of MEO position for easier detection in the field and demining.

Examples of MEO records with incomplete information - pic.2.1.3

The image shows two examples of MEO records. Each record is a form titled 'ZAPISNIK MINSKOEKSPLOZIVNE PREPREKE [MEP]' (Record of Minsk Explosive Obstacles [MEP]).

**Left Record (Sujica Parolud):**

- Reg. broj Serija: 5G
- Karta: S. 5
- Indicije: A - PODACI O IZRADI
- Orijentirna tačka: 121 - Bunker
- Način izrade: Ručno
- 1. Vrsta MEP - količina ugrađenih MES: 10 kuglica i 2 granate
- 2. Način izrade MEP: Ručno
- 3. Broj redova (grupa) u MEP-količina ugrađenih MES po redovima-grupama: 1. red 4 kugle, 2. red 2 kugle, 3. red 1 granata
- 4. Podaci o eksploziva u MEP: nemo
- Datum izrade: 1.10.1993

**Right Record (D-1570):**

- Reg. broj Serija: 84
- Karta: R. 12
- Indicije: A - PODACI O IZRADI
- Orijentirna tačka: KOSTJANYANJE 1000G MINSKOEKSPLOZIVNE PREPREKE 06-01-1973
- Način izrade: Ručno
- 1. Vrsta MEP - količina ugrađenih MES: PAKET 21 700G
- 2. Način izrade MEP: Ručno
- 3. Broj redova (grupa) u MEP-količina ugrađenih MES po redovima-grupama: 1. red 21 paketa
- 4. Podaci o eksploziva u MEP: nemo
- Datum izrade: 22.3.94

It is necessary to use other available information as auxiliary information or mine indicators that are related to obstacles in relevant area during analytic determination of MEO records positions, for which we do not have precise information.

Furthermore, information in MEO records can contain a number of other useful information that can be helpful in research of mine state of adjoining areas. Although that data, in specific case may appear unimportant, through the analysis of the available records, it is necessary to register that data for wider analytic purpose.

### Information from the record and their purpose in research of mine-explosive obstacles

No.	Type of information	Wider analytic purpose of information
1.	<b>Numbers and registration of MEO record:</b>	- Grouping of records according to registration numbers, sequence of placement of MEO by ascending numbers, grouping of records that are related to changes in MEO (repair, add on, opening/closing manway etc) determining record duplicates, ... - numerical link of the record with MEO on cartographic bases (military maps, analytic maps) and other MEO records
1.1	- original military number / manufacture year	
1.2	- according to database	

<b>2.</b>	<b>Cartographic information:</b>	- Geographic-topographic orientation in the area of MEO.
2.1	- name of the map	- Selection (or filtering) of the record to the areas, local communities, land objects etc.
2.2	- number of paper	
2.3	- scale	- Assessment of the terrain by the map where obstacle is placed
2.3	- local community/ settlement	(it is necessary to enter available information in correspondent box in analytic form, although information is not stated in the record)
2.4	- land object	
<b>3.</b>	<b>Local name of the area of the MEO position</b>	- Grouping of records according to local name of MEO position (local name is not entered in a topographic map) Contact information in the field according to local names
<b>4.</b>	<b>Orientation information for detection of MEO in the field</b>	- Reliability assessment of data, according to MEO record – detection of MEO in the field - Polygon drawing of MEO in adequate cartographic base and in adequate scale - Grouping of records that correspond to given coordinates and/or main orientation point and/or auxiliary orientation point - To improve, by comparison and linking of MEO data, precision for orientation in detection of MEO (available data on the map is either achieved by analytic procedure or are precisely determined – it is necessary to enter them in correspondent box in analytic form together with available information from the MEO record)
<b>5.</b>	<b>Type and number of placed mines</b>	- the status of MEO is determined through further analytic procedures by comparison of data on type and number of placed mines, according to MEO record with information from the other sources
5....	- antipersonnel	
5....	- antitank	- Assessment of area mining in respect to spent mines and/or in respect to expected cost, according to particular situation. - Additional research according to kinds and types of mines in MEOs in the area, using analogical data application in particular situation.
<b>6.</b>	<b>MEO characteristics:</b>	- General assessment of carried out MEO in the area according to field conditions and organisation of defence system, according to particular situation.
6.1	- antipersonnel MEO	
6.2	- antitank MEO	
6.3	- mixed MEO	- Analogical data application for manner of MEO assessment in the area (front defence line, second defence line, flank defence, tank ways, in front of defence zone, “surprise” mines)
6.4	- terrain conditions at the MEO location	
6.5	- lay out of mines in MEO	- Analogical data application on MEO distances from firing position in particular situation (meters)
6.6	- width of MEO	
6.7	- depth of MEO	- Assessment of danger line in respect to explosion action zone of mine-explosives (wounds, death)
6.8	- link with firing position (type, distance)	
6.9	Position of MEO in respect to combat unit formation)	

7.	<b>Fabrication of MEO:</b>	Grouping of records, according to following information: - information on chronology of MEO fabrication, - information on features in MEO fabrication of specified unit or head of MEO fabrication, - information on units holding positions in the area with assessment of combat defence lay out, - contact with persons for further information collection
7.1	- date of MEO fabrication	
7.2	- unit that fabricated MEO	
7.3	- head of MEO fabrication	
7.4	- unit that MEO was fabricated for and/or MEO record was delivered to	
7.4	- persons that are aware of fabricated MEO	
8.	<b>Final usability assessment of MEO information ( from "0" to "10")</b>	Determination of reliabilities gained from procedures of analysis and linking of all available data that were used in analytic preparation and are related to set mine-explosive obstacle according to MEO record. Definition of requirements for collection of additional data in the field that will help to more locate more precisely MEO position or MSA assessment: using information on combat units lay-out, information on fortification and terrain characteristics.
8.1	- polygon drawing of borders	
8.2	- type and number of placed mines	
8.3	- mines lay out	
8.4	- description of state and special requirements for collection of additional data	

Final usability grade of the information from each record gives authenticity of shown state, and points to additional data that is required for more precise positioning and determination of MEO borders. Data authenticity on analysed MEO tells us how much can we rely on achieved information concerning particular MEO in order to use it in research of obstacles in surrounding area.

Final goal of MEO records analysis, using analytic preparation, is to present as many as possible positions of MEO, and, in accordance with achieved precision and requirements, to set precise requirements for additional data collection.

Analytic data according to MEO records are entered into Excel sheet, which will enable clear overview of data, attribute linking and perception of relevant indicators in research of mine-explosive obstacle.

Additional data can be found using further analytic preparation tasks. All new information should be added to analytic table, their influence onto already available data should be discovered, and borders of mine-explosives obstacles should be updated and reconstructed in total.

Presentation of analytic data on mine-explosive obstacles in analytic table will prove to be of great help in research work, especially when we have at our disposal a greater number of records, and when we are researching obstacles in wider area.

As a research model example of available MEO records, we will show analysis results of mine-explosive obstacle of land objects Vujatovo brdo (hill) and Varošina:

Mine-explosive obstacle contains 276 antipersonnel tripwire activated mines, laid in 4 rows, in length of 1750 m and 20 mines for direct action. Number of tripwire activated mines is different, which indicates that mining density was adapted in order to replace activated mines (adding up mines) and/or stronger reinforcement of defence line in particular parts. Direct action mines are placed on Vujatovo brdo, in defence zone of four bunkers, and most probably are the first mines in front the position in frontal part of defence. There is a manway leading through antipersonnel mines in Vujatovo brdo, which indicates to possible presence of position and MEO in front-field of available line of defence.

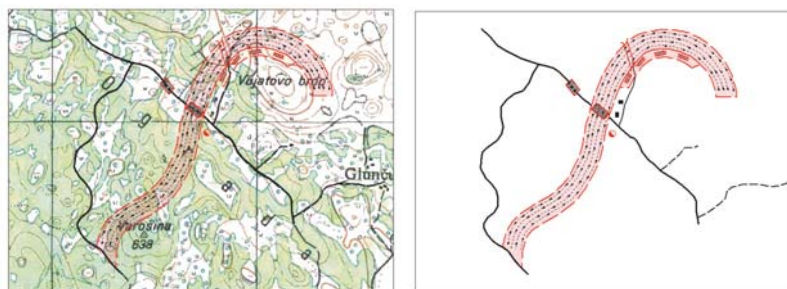
MEO in analytic table (detail) - pic.2.1.4

Analiza minskoeksplozivnog zaprečavanja prema zapisnicima MEZ

Broj	Broj evidencije zapisnika NEZ		Kartografski podaci područja minskoeksplozivnog zaprečavanja					Podaci za orijentaciju u određivanu pozicije minskoeksplozivnih zapreka								
	Baza podataka	Vojni broj	karta	mjerilo	list broj	naselje/ lok.zajed.	zemljišni objekt	orijentirna točka (ot)	koordinate gt		pozicija MEZ od gt	pomoćni orijentiri	Kordinate			
	1	2	3	4	5	6	7	8	9	x	y	12	13	14	X	Y
5	32557	44/93	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Vujatovo brdo	35650 44400	37000 44400					35790	43980
6	32316	79/94	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Križanje puta za Iugarsku kuću	35500 35790	48200 43980		298				
7	32519	84/94	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Varošina	35650	37000					35790	43980
8	32639	93a/94	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Osmatračnica Vujatovo brdo	36200	44300						
9	32485	06/95	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Varošina	35650 44400	37000					35790	43980
10	32743	09/95	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Bunker na Vujatovom brdu								
11	32484	10/95	Gospić	50000 25000	4 419		Vujatovo brdo - Varošina	Bunker kod Iugarske kuće uz put.	35750	44070		70				

Grouping of records by land objects (Vujatovo brdo – Varošina) and sequence of MEO fabrication

Polygon drawing of mine-explosive obstacles according to MEO record analysis (Military record numbers: 44/93, 79/94, 84/94, 93a/94, 06/95, 09/95, 10/95) - pic.2.1.5



Antitank groups are fabricated of 23 antitank mines. The groups of mines are located within the reach of the main road that passes between Vujatovo brdo and Varošina. A group of two mines is placed north of Vujatovo brdo on unknown location, which indicates to possibility of tanks movement outside the main road, and presence of obstacles in front of rows with antipersonnel mines.

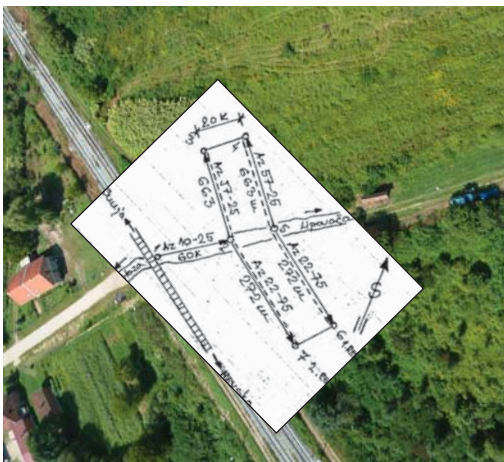
Feasibility of shown borders on the map is 2.4 for antipersonnel and 9 for antitank obstacles (from "0" to "10"). In order to improve MEO borders, it is necessary to gather date on firing positions that are probably placed on slope Varošina-Ograda-bunker by the main road- structural building from byway to Vujatovo brdo-slopes of Vujatovo brdo.

Specified information appears through analysis of available MEO records, and it appears as mine indicator that will, by linking procedures and comparison with other information, help to in research of mine-explosive obstacles in the areas where we have insufficient mine indicators.

## Types of indicators that appear in MEO record analysis

No.	Information - indicator	Description of indicator's characteristics	Task of "research"
1	Original MEO record numbers	Absence of individual MEO records according to ascending record numbers	Determine- asses possible positions of MEO for unavailable MEO records
2	Firing action objects	Matching presence of firing objects with mine-explosive obstacles	Determine type and position of the firing action object within defence position. Determine- assess presence and distance of MEO from the firing object. Reconstruct combat formation using firing action objects.
3	Fortification obstacles	Matching presence of fortification obstacles with mine-explosive obstacles	Determine- assess line or positions of fortification obstacles. Determine- assess presence of mine-explosive obstacles (mines) in fortification obstacles and nearby.
4	Location of MEO	Analogy of obstacles from other locations with same characteristics	Determine- assess locations with other locations that we have MEO records for.
5	Type and number and/or mines' lay-out	Spatial frame where MEO is laid according to characteristics of mines	Determine- assess borders where MEO is laid in field, zone of lethal and harmful action.
6	Strength of the unit that MEO was fabricated for	Doctrinaire principles of defence using obstacles	Determine- asses defence lines of the unit according to strength – organisational structure and field conditions with obstacles.
7 etc.	Manways in MEO	Indicator of military activities in front of MEO	Determine- assess presence of firing positions and MEO in front of available MEO.

Example of mine indicator for analogical application according to location of lay-out of available MEO (mine-explosive obstacle in front of railroad used as a base for firing shelters) - pic.2.1.6



Determination of MEO position according to record sketch



Reconstruction of MEO polygon according to the record with assesment of obstacles belt in front of the railroad



MEO is 60 paces (or 45 m) far from the railroad. Mines are laid in two rows. They are trip-wire activated (PROM-1 and PMR-2A). Space between rows is about 20 paces. Frontal width of mining is about 900 metres. MEO is covered by fire up to 400 metres from the railroad mound. There is no manway in MEO.

**Situation:** Mine-explosives obstacles of defence lines on the railroad were fabricated in the belt from 45-400 m in front railroad N/W and S/E from available MEO (status: February 1992)

## 2.2 Record analysis on military demining

Records on military demining of mine-explosive obstacles (demining records) are the original documents on military demining (or removal) of mine-explosive obstacles.

Military demining records are made by military units that have removed mine-explosive obstacles. Mining records of "VSK – Army of Serbian Krajina (ASK)" have possibility of entering information on demining in the same document.

Military demining is carried out by the units during war, when according to military situation need for mine-explosive obstacles ceases to exist.

According to military situation, units will remove own mine-explosive obstacles and obstacles laid by the enemy (completely or partially). In war, obstacles are usually demined in order make ways in attack directions.

Complete military demining of land and objects can be done during war or immediately after it, in freed or controlled areas that are necessary for further war engagement and/or after war recovery and return of local population.

Demining record of Croatian Army - pic.2.2.1

This is a detailed demining record form from the Croatian Army. It features a header with the title 'DELOVOJNE RAZMINERANJA' and the location 'M.P. KISINAC ŽAN - BULVAR'. The form is divided into several numbered sections:

- Section 1:** General information including date (15.02.1992), location (KISINAC ŽAN), and coordinates.
- Section 2:** A table with columns for 'Vrsta mina' (mine type), 'PO mine' (mine type), 'skupina' (group), 'prilaz' (approach), 'maka' (mark), and 'razminiran' (demined). It contains data for '40' and '40' mines.
- Section 3:** A hand-drawn map showing the mine layout with labels like 'KISINAC ŽAN', 'BULVAR', and 'MINE'. It includes notes such as 'MINE RAZMINIRANE SA SVAKO STRANE SA PO REKA TUP'.
- Section 4:** A table for 'Razminirani objekti' (demined objects) with columns for name, address, and coordinates.
- Section 5:** A table for 'Mehanizam naprava' (mechanism of devices).
- Section 6:** A table for 'Eksploziv' (explosive).

Example of demining record with incomplete information - pic.2.2.2

This is a demining record form with missing information. The header includes 'DELOVOJNE RAZMINERANJA' and 'broj: 4788'. The form structure is similar to pic.2.2.1 but with significant omissions:

- Section 1:** General information with some handwritten entries like 'KISINAC ŽAN'.
- Section 2:** A table for mine types, but it is mostly empty.
- Section 3:** A hand-drawn map showing a mine layout with labels like 'KISINAC ŽAN', 'BULVAR', and 'MINE'. It includes notes such as 'MINE RAZMINIRANE SA SVAKO STRANE SA PO REKA TUP'.
- Section 4:** A table for demined objects, but it is mostly empty.
- Section 5:** A table for mechanism of devices, but it is mostly empty.
- Section 6:** A table for explosive, but it is mostly empty.

In the zone of battle activities, and especially on transport communications, demining activities were partially conducted by UN peace-keeping forces. On freed areas, complete demining is conducted, either by military forces, or by other state special organisations such as Ministry of Interior Affairs units and civilian protection.

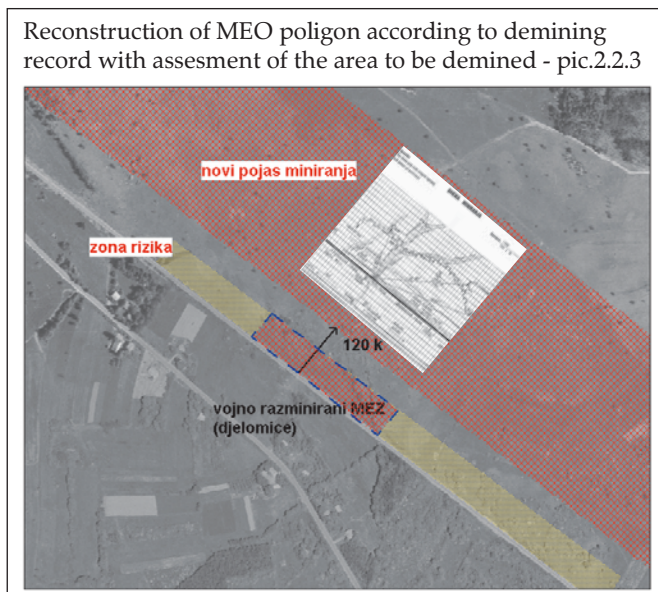
In research of mine suspected areas, information on military demining has two-sided role:

1. To use it for research of mine-explosive obstacles due to the lack of original information on mining and
2. To determine a status of the area, where military demining was conducted, in order to determine presence or absence of mine threat due to the military demining in war.

Practice in humanitarian demining shows that available MEO records do not provide complete and precise information on mine-explosive obstacles in the areas of war military activities.

Records often do not exist for all placed MEO in area or available records do not include precise information (or there is not any) on location of MEO, type, quantity and lay out of mines, information on manways, information on reinforcement of available MEO, information on executors and other information on MEO according to concrete situation.

It is, hence, necessary to determine, through detailed analysis, reliability of available MEO records, missing information, and imprecision in records, and define status of mine-explosive obstacle in sense of its absence, partial demining or possible presence of left-over mines.



Information in military demining records of MEO contains also information that helps in research procedures of mined area, so that information should be also recorded like mining records. During the MEO analysis in analytic preparation, demining information should be used for more precise determination of mine-explosive obstacle organisation by linking it to other information. A status of MEO that was military demined is determined upon completion of reconstruction of mine-explosive obstacle.

Data record on military demining should be kept in the database in the same way as mining records are kept.

Final usability grade of the information should give an answer on authenticity by each of the records, and should define which information is missing for confirmation of carried-out demining, or it should determine in which scope MEO was demined.







During demining of the specified MEO in accordance with available records, finding of lesser or greater number of mines or the other types of mines, should be followed by further analysis and linking to information, in order to detect reason for presence of such a state.

## 2.3 Mine incidents analysis

The records on mine incidents are the original information on places of mine and other ordnances activation with human or animal casualties. The records on mine incidents are usually very strong indicators of mine danger. Hence, they require a detailed analysis in mine-explosive obstacles research.

Other indicators that are important for assessment of MSA and humanitarian demining activities can be found by data analysis of mine incidents, available information on mine-explosive obstacles can be confirmed, unknown obstacles can be found.

(Criterion for determination of demining priorities in the areas of frequent mine incidents in local population).

ZNACI MINSKIH INCIDENATA	
	minski incidenti pripadnika HV
	minski incidenti pripadnika "VSK"
	minski incidenti civilnih osoba
	minski incidenti pirotehničara
	minski incidenti domaćih životinja
	minski incidenti divljih životinja

Positions of mine incidents are drawn on topographic maps. A visual identification is achieved by selection of symbols in accordance with the type of incident, and this is necessary for linking with other information in further analysis

In case that precise information, on mine incident position (place of mine-explosive ordnance activation) was not obtained in data analysis, a wider area will be marked on the map where mine incident has occurred.

In mine incident research, primary information on mine incidents is related to precise determination of the position where mine-explosive ordnance has activated, type of the activated ordnance and activation date.

Since mine incidents are a strong mine indicators, information on each incident, be it war or peace time one is equally important.

It is necessary to keep mine incidents records in a special database with display of relevant indicators that will help in mine-explosive obstacles research.

It is useful to determine which warring party provoked a mine incident that has occurred during a conflict, and under what circumstances. This information can help in mining research in accordance with warring parties, in precision assessment of keeping records on mining and/or assessment of complete mine situation in the area. Hence, for example, mine incidents that have occurred in own zone of defence can point to following situations

- Units did not keep mining records, or their information is imprecise, or
- the opposite party held those same positions and carried out specified lay-out of obstacles, or
- Parties in conflict entered each other's space and conducted inconspicuous mining etc.

Local population casualties can be indicator of imprecisely defined MSA or usage of area within MSA at own risk.

Deminer's casualties can indicate to inappropriate work organisation or lack of observance of work regulations.

## 2.4 Data analysis on found mines

Information on found mine-explosive ordnances in the field is detection of mines, parts of mines, mines bunks and/or mine explosions. This does not concern detections of mines by demining and mine incidents.

Information on found mines in the field as factual information has special importance in confirmation of mine presence and their position in accordance to available mining records and detection of unknown mine-explosive obstacles



(1) PMA-3 Vrhovina area



(2) PROM-1 Pristeg area



(3) TMA-5 Barleta area



(4) PMR-2A Promine area  
(Precise mine position  
According to MEO record  
no. 50175)



(5) Trip-wire for PMR-2A  
(Precise position of wire ring,  
at unknown MEO location)



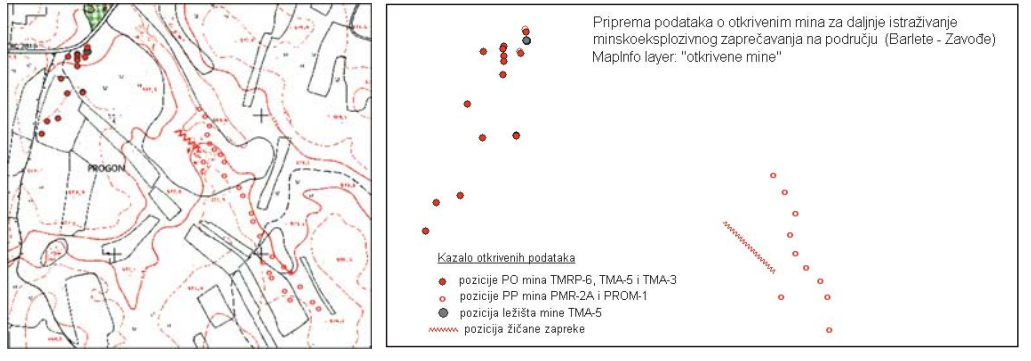
(6) TMRP-6 Barleta area  
(Precise mine position at  
unknown MEO location)

In organisation research of mine-explosive obstacles, relevant detected on found mine-explosive ordnances are related to precise determination of the position, type of ordnance and date of detection. Information o detected mines, parts of mines, mine bunks and/or mine explosions is equally important.

Analytic data on mine position, parts of mine, mine bunk and/or mine explosion are drawn onto the map in order to link them to other data. Imprecise positions are shown in wider space of the detection area.

Information records on detected mines should be kept in special database with relevant indicators that will help in mine-explosives obstacles research.

Positions of detected mines according to coordinates of detection location (Barlete area) - pic.2.4.2



## 2.5 Analysis of humanitarian demining projects

Humanitarian demining projects (demining projects, technical survey projects) contain data on earlier assessments of MSA state in the area where demining activities were conducted. Expected mines, from known mine-explosive obstacles, are found as well as mines from unknown MEO by demining activities.

Demining projects analysis is very important in order to determine whether known MEO in the project were completely demined, in what scope, whether there were found unknown MEO and what kind of other directions and ways of mine-explosive obstacles can be expected in the area that surrounds demined area.

In demining results analysis procedure, data on found mines are compared with the data on mine-explosive obstacles that were a topic of demining.

Results discrepancies obtained by demining in comparison to project information, require more detailed examination of the reasons and possible influences on assessment of MSA state.

Characteristic demining results that require detailed research:

- found mines correlate to type and number but are found outside known MEO (Assessment: The available MEO was demined, but polygon MEO display is imprecise, the actual MEO borders are not well defined) It is necessary to correct MEO borders in accordance to found mines.,
- found mines correlate to type but are outside of the reconstructed MEO borders towards the edges of the demining project, and/or number of found mines is lesser than expected (Assessment: expected MEO was demined within project

Demining results: found mines correlate to type but are outside of MEO reconstruction- pic.2.5.1



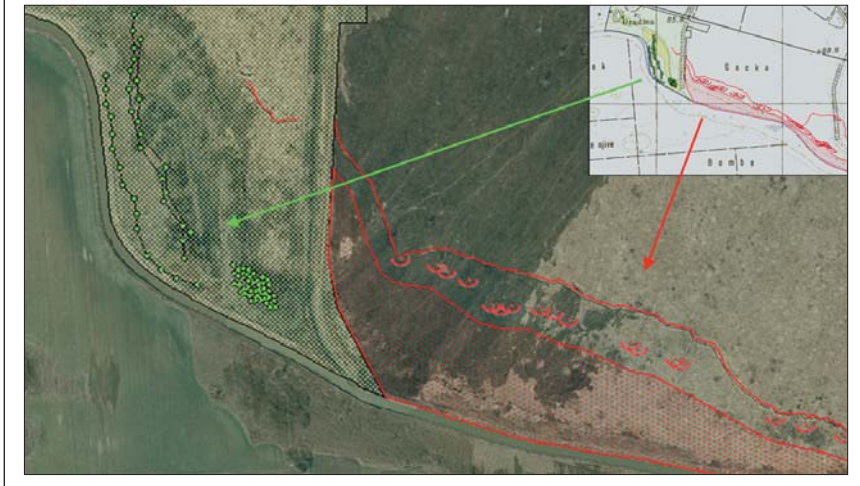
area as a safety MEO position, or MEO is outside project and is not completely demined). It is necessary to draw in MEO borders – correct them according to found mines and with aid of new reconstruction conduct research of further directions of MEO outside project area).

- found mines correlate to type but number of found mines is greater than expected and their lay-out is unclear (Assessment: MEO was added up and/or there is unknown MEO or parts of unknown MEO also located in unique mining belt and/or MEO were placed in new battle situation and there is no information).
- Other types of mines were found in borders or narrower regions of MEO (Assessment: MEO was restored or fortified with other types of mines or there is unknown MEO according to situations mentioned in previous example).
- Expected MEO was not found (Assessment: MEO is not included in project area, MEO was military demined or removed by unknown executors, and information on MEO is false). It is necessary to carry-out control of MEO positioning or by further steps determine real situation.
- Unknown MEO was found by demining (it is necessary to use information in further research of MEO organisation in that area).

Analytic data of demining results are drawn into a special map for research by linking with the other analytic data.

Information records on found mines in demining projects should be kept in special database with relevant indicators that will help in mine-explosives obstacles research.

Assessment of the area for demining according to the information obtained from found mine and fortification objects, in DOF2 - pic.2.5.2



For the purpose of mine-explosive obstacles research, it would be useful to have requirements to keep records on fortification objects and other mine indicators, as one of the project tasks of the humanitarian demining project.

## 2.6 Military maps analysis

Military board map is a topographic or thematic map or other display of terrain where information on preparation and execution of combat activities are shown with graphic and descriptive explanation.

Military board map (military map, map) is a combat document that gives visual overview of units' lay-out or state of combat situation using drawn tactical symbols, abbreviation and textual explanations.

Military maps are kept on the level of battalions, brigades and on higher levels (corps, operational zone, military zones).

Regimental and lower commanding officers use maps for execution of specified tasks and upon task completion these maps are destroyed. They are rarely found as available documents.

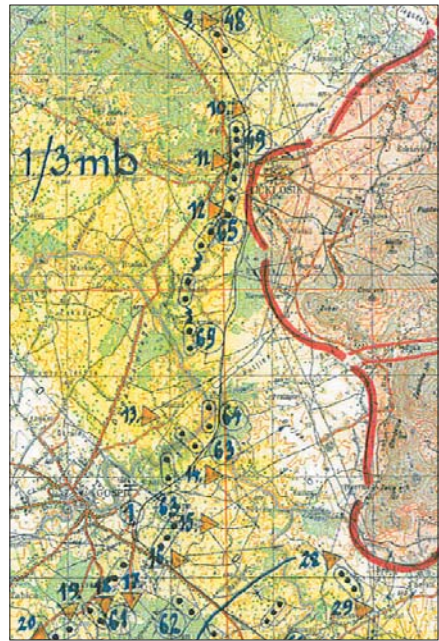
In the lack of original information on mine-explosive obstacles and from the necessity research MEO using mine indicators, information obtained from military maps has a great significance.

Military maps can contain information about the place and lay-out of the units, units' line-up, responsibilities, directions and goals of offensive-defensive activities, information on obstacles, fortifications, demolitions, units names, time or period of shown state on the map and other information.

Example of available military maps (Gospić area) - pic.2.6.1



Information "ASK" combat lay-out



Information CA: MEO positions, number

During analysis it is necessary to categorise military maps according to areas, conflict parties, units, and within each unit they should be categorised according to type and purpose of the map, information content and chronology.

Comprehensive information on situation in specified area is given on the command and head-quarters maps. Completeness of information serves as a basis for detailed viewing of individual completeness by specialties using other maps and combat documents that are elaborated at specified command level.

Military map analysis, area: Peručko jezero (lake) (detail) - pic.2.6.2

broj	Izvorni naziv sa karte	Datum stanja	kartu izradio	Opisni podaci o sadržaju karte
1	Raščlamba inženjerijskog osiguranja "Oluja"			Zona odgovornosti 6.dp, zadaci postrojbi inženjerije 6.dp, gl. pravac djelovanja
7	Evidencija utvrđenih objekata 1.lbr		VSK	Pozicije minskih polja, bunkera, skloništa, art.položaja, linije tampon zone
8	Karta evidencije UT 7.K		VSK	Pozicije bunkera za pm i m (drveno zemljani), skloništa (drveno zemljana), zaklona za art. oruđa
9	nema		?	Pozicije minskih polja VSK (približne pozicije prema zapisnicima MEZ)
18	Zemljovid OB osiguranja OG Šibenik - Sinj	1.1.1994 - 1.4.1994	HV	Elementi borbenog rasporeda VSK: koncentracija snaga za POB na tenko prohodnim pravcima uz Peručko jezero
22	Raspored snaga	15.01.1994.	HV	Položaji na prednjem dijelu obrane
35	Plan POB-e		HV	Lokacija sredstava za protuoklopnu borbu u zoni odgovornosti 126 br HV, linije prednjeg dijela
36	Raspored snaga	31.12.1994.	HV	Prednja linija obrane
37	Obostrani raspored do dolaska mirovnih snaga UN-	1992.	HV	Zona razdvajanja snaga južno od HE "Peruča"

Thus for example, maps that are kept on the brigade level are: engineering protection, artillery, artillery-rocket units and anti-aircraft defence, armoured units, intelligence, communication (signals), logistics maps and other maps.

Specified information on special maps can be somewhat different from the basic map that was elaborated by the command. In those cases, it is necessary to treat such information with caution. There could be differences in drawing precision or new situation. When we talk about information relating to mine-explosive obstacles, it is necessary to determine real situation. It is necessary to look at more solutions until the real situation is determined.

## 2.6.1 Data analysis on engineering protection

Information is kept on obstacles, fortifications, demolitions and se of engineers units in offensive-defensive activities for the engineering protection requirements. Also, available information on enemy units lay-out, laid obstacles and carried-out demolitions is kept. Information on engineering protection on military maps are a very strong mine indicator.

**2.6.1.1 Information on mine-explosive obstacles** on military maps is shown with prescribed tactical symbols in position where mine-explosive obstacle was placed.

As a rule, display of placed MEO on the map should contain important information from



MEO record: record number, type of MEO (AP, AT and mixed), number of placed mines (AP, AT), way of activation (pressure, trip-wire), width of mine field (metres or paces) and other operatively important information (manways etc.)

Display of planned mine-explosive obstacle contains planning information, such as: lines of MEO placement and/or planned MEO positions, units that are to place MEO and planned expenditure of mine-explosive ordnances for fabrication of MEO. Clearly, there can be discrepancies in respect to planned expenditure of ordnances during placing of obstacles. Thus, this information has to be checked through other analytic preparation tasks and/or data collection.

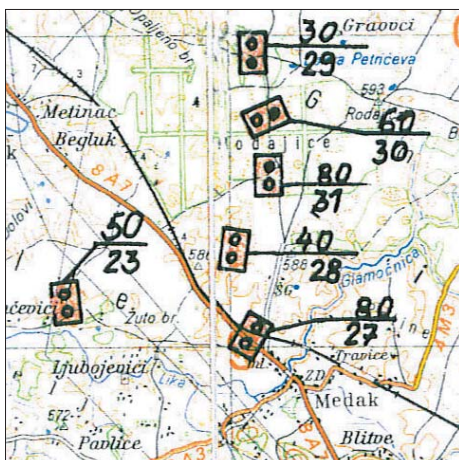
Tactical mine-explosive obstacles symbols - pic.2.6.1.1.1

	Protivpešađijska mina: — nagazna, i — potezna.	PPM PPMn PPMp	Neprijateljstva NkM se označava plavom (umesto) crvenom bojom.		Mešovito minsko polje	MMP	U brojtelju se označava broj PTM, a u imenitelju PPMn i PPMp.	
	Protivtenkovska mina	PTM			Prepreka na reci od mesnog materijala			
	Nuklearna mina	NkM			Prolaz u mitskom polju: — za pešadiju,			
	Mina iznenađanja	Mi			— za tenkove i ostala vozila			
	Dirigovana mina (fugaša): — kamenometna, — obična, — plamena, i — hemijska.	DirM(F) DirFk DirFo DirFp DirEh						

Source: GŠ JNA "Instructions on board map" – 1979

Display of adversary mine-explosive obstacles contains information on mining that was gathered from various sources: sighting of MEO fabrication, MEO scouting in order to make manway and to demine MEO, capturing documents and other intelligence ways.

Information map according to MEO records  
Gospić area – Medak - pic.2.6.1.1.2



Information: position, type, MEO width, record number

Information map on MEO presence MEZ




Information: frontal defence, position, MEO type, defence areas reg 2.pb with lay-out in one line

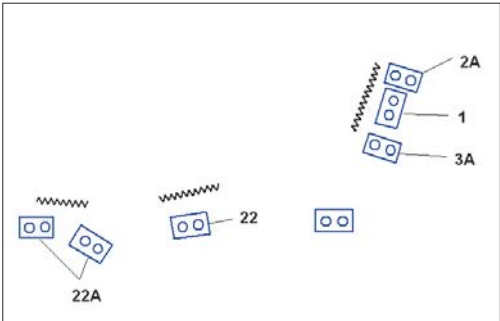
In analytic phase of data research using analytic preparation, it is necessary to precisely copy all information on obstacles from military maps to analytic maps for parallel comparison with other information. It is necessary to mark and/or describe a defined MEO status according military map for the purpose of further research procedures.

Information on fortification obstacles are shown on mine-explosive obstacles analytic maps considering that fortification obstacles, as a rule are fortified with mines and/or mine-explosive obstacles are laid in their vicinity.

Example of the map of obstacle record  
Information: position, MEO type, record number, wire obstacle position and obstacles on main road



Analytic data preparation for reaserch by linking with other data



It is necessary to determine, by analysis of mine-explosive obstacle, whether there are already known data on specified obstacle that is shown on the map or it is new data. Thus, it is necessary to determine whether on MEO position according to the map there is any information on MEO according to previous analysis of mining records, demining records, mine incidents, information on found mines, humanitarian demining and other analysis.

Using analysis of cartographic data on obstacles, it is very important to determine whether there are planned activities or real state in the field and this will have an impact on final reliability assessment of obtained results.

**2.6.1.2 Demolition information** is drawn onto a military map using prescribed tactical symbols according to locations of executed and planned demolition.

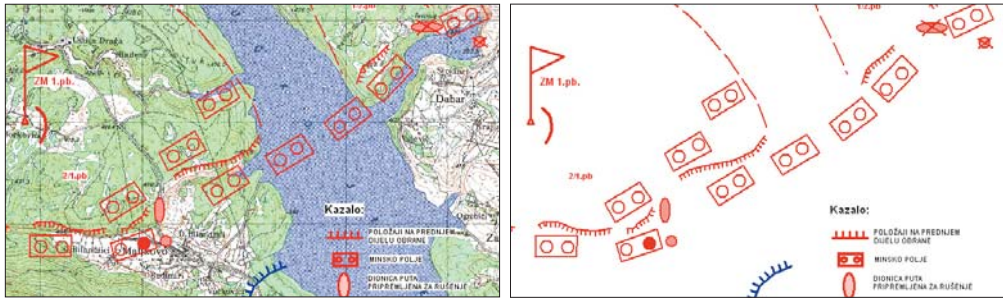
In the analysis of mine-explosive obstacles, according to information on demolition, it is necessary to consider information's dependency and connection to other indicators in the defence system organisation in the topic area, which was reached using carried-out analytic preparation tasks.

Information on demolition should cohere with defence organisation on channelled – passable directions for armoured units and with lay-out of antitank fight resources.

Furthermore, information on demolition should cohere with positions of mine-explosive obstacles around the demolition location and/or show possible presence of undetected obstacles.

In analytic phase of data research using analytic preparation, it is necessary to precisely

Obstacle plan with demolition in front defence line "ASK", Peručkog jezera (lake) area - pic.2.6.1.2.1



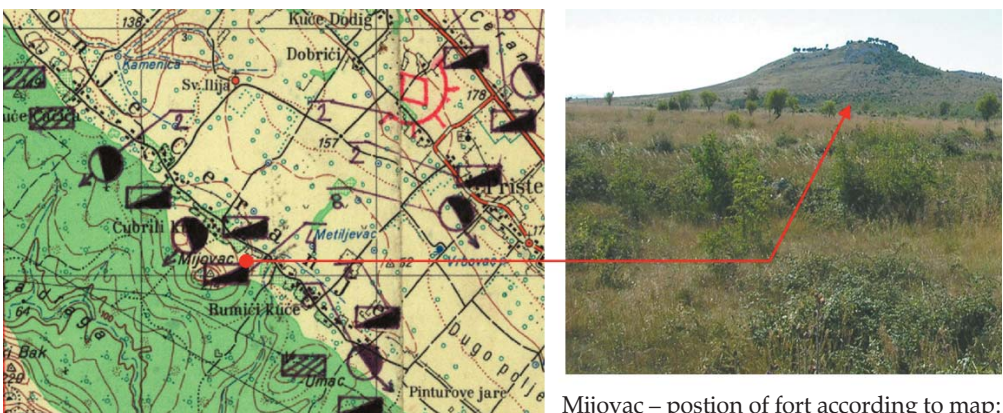
copy all information on demolition from military maps to analytic maps for parallel comparison with other information.

Based on demolition information, and without other relevant indicators on mine-explosive obstacles on directions and in the demolition zone, analysis is directed to contents of combat activities and passability of terrain in particular conditions. It is necessary to determine narrow- channelled passable routes and critical places that can not be avoided and as such these places can be potential locations of demolition and/or mining obstacles. In those cases, logically mined areas will be assessed with greater safety zone of possible mining as mine suspected area.

**2.6.1.3 Information on fortification** is shown on a military map using prescribed tactical symbols. Maps contain planned fortification and information on previously built fortifications.

In the mine-explosive obstacle analysis according to fortification information, it is necessary to consider information's dependency and connection to other indicators in the defence system organisation in the topic area, which was reached using carried-out analytic preparation tasks.

Map of engineer's territory design: fortification, Benkovac area – Pristeg - pic.2.6.1.3.1

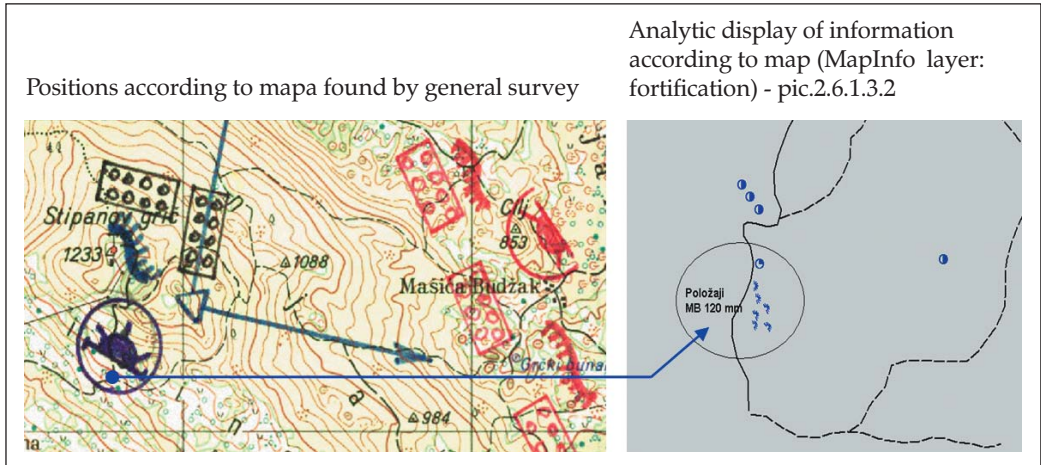


Information: positions of bunkers, tank shelters and covers Mijovac – position of fort according to map: bunker and 4 men and materials shelters

In analytic phase of data research using analytic preparation, it is necessary to precisely copy all information on fortifications from military maps to analytic maps for parallel comparison with other information.

Fortification information should cohere with defence lines and/or show unknown elements in battle formation especially defence depth, auxiliary positions, firing positions according to type of weapon and other (safe routes to positions).

Also, fortification information should cohere with positions of mine-explosive obstacles and/or show possible presence of undetected obstacles.



Based on fortification information, and without other relevant indicators on mine-explosive obstacles on directions and in the demolition zone, analysis is directed to contents of combat activities according to doctrinaire principles of mine-explosives obstacles in particular conditions. In those cases, logically mined areas will be assessed with greater safety zone of possible mining as mine suspected area.

## 2.6.2 Data analysis on units' lay-out

Military maps can contain information about military activities areas, line-up and lay-out of units, responsibilities and offensive-defensive directions.

It is necessary to determine (or assess) by data analysis on units' lay-out elements that influence organisation of mine-explosive obstacle, defence zones of individual units, number of placed defence lines, line of frontal part of defence, lay-out of lines by depth, position of combat protection, lay-out of forces or resources for anti-tank combat, presence of remote posts (artillery and rocket positions).

It is necessary to precisely copy all information that influences organisation of mine-explosive obstacles from military maps to analytic maps for parallel analysis

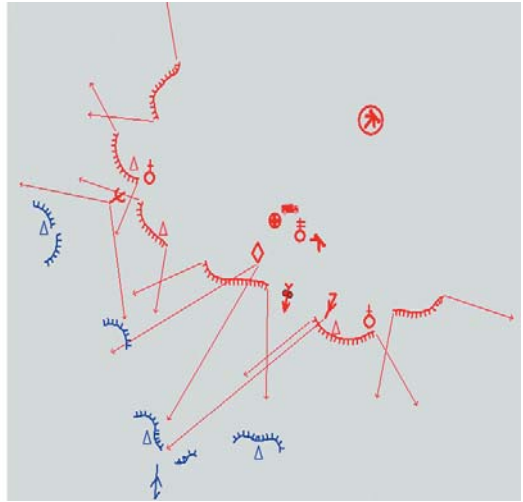
Information on units' lay-out should cohere with some of the already known data on mine-explosive obstacles or mine indicators. It is important to determine by parallel analysis whether all defence lines and individual positions are protected by obstacles.

If based on information on lay-out of units, relevant mine indicators in the area are not determined, it is necessary to assess lines and zones of mining according to doctrinaire principles of defence in particular terrain conditions.

Elements of regiment's combat lay-out



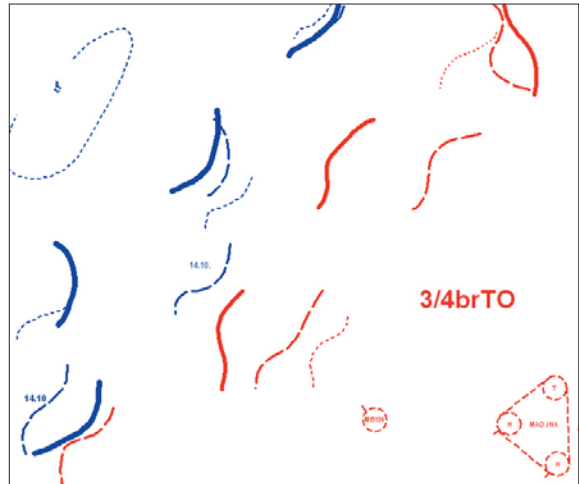
Analytic display according to the map for linking with other data (MapInfo layer: combat lay-out) – pic. 2.6.2.1



Map of bataillon combat lay-out "ASK"  
Informantion: line of frontal defence line, forces



Chronology of forces lay-out according to maps (research of positions movement) - pic. 2.6.2.3



Kazalo obostranog rasporeda snaga:  
 - - - - - početak rujna 1991. godine  
 - - - - - rujna - studeni 1991. godine  
 - - - - - 01.03.1992. goddine

Information on fortification obstacles are shown on mine-explosive obstacles analytic maps considering that fortification obstacles, as a rule are fortified with mines and/or mine-explosive obstacles are laid in their vicinity.

It is necessary to research whether there was new mining, demining and/or moving of mine-explosive obstacles by tracing information on units' lay-out, and noticing specified positions or lines movements due to military activities or other circumstances (peace agreements etc.).

It is necessary to check by field surveys information on units' lay-out according to map and to detect real positions of firing positions.

In lack of other information on mine-explosive obstacles, detected firing positions in the field will give the most precise information on combat lay-out and good possibilities to assess mine-explosive obstacles.

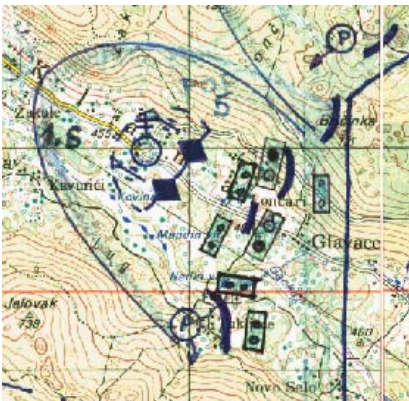
**2.6.3 Information on anti-tank combat units (ATCU)** are shown on military maps using prescribed tactical symbols according to stationing of forces and/or prepared firing positions for take-over and/or transfer during combat.

By analysis on ATCU, it is necessary to determine their positions that will at the same time reveal tank-way directions and anti-tanks obstacles. These locations or positions can be stations of battalion anti-tank group; regimental anti-tank groups; individual ATC resources and tank positions. Remote and more important posts of ATCU, such as tank positions, can be directly protected by mine-explosive obstacles.

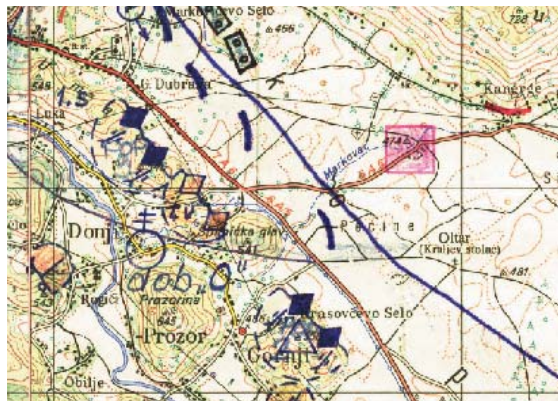
It is necessary to precisely copy all information on use of ATCU from military maps to analytic maps for parallel analysis, in order to make easier parallel analysis and data linking.

Information on anti-tank combat units lay-out should cohere with some of the already known data on mine-explosive obstacles. It is important to determine by parallel analysis where tank-way directions were protected by anti-tank obstacles.

Regiment's lay-out on-tank-way  
(Information on obstacles in frontal  
defence part) - pic. 2.6.3.3.1



ATCU lay-out on land passable by tanks  
(no information on expected obstacles) - pic. 2.6.3.2



If based on information on lay-out of units, relevant mine indicators in the area are not determined, based on ATCU lay-out, their firing capabilities and terrain conditions, it is necessary to assess positions of mining according to doctrinaire principles on organisation and defensive anti-tank combat.

**2.6.4 Information on artillery** is shown on military map using prescribed tactical symbols, according to firing positions and artillery operation plan.

It is necessary to determine by data analysis remote artillery locations outside of battalion defence zone. Mine-explosive obstacles can protect these positions from enemy scout-commando troops.

It is especially important to find out artillery tasks (firing plan) in order find out enemy combat positions and hence mined locations.

It is necessary to precisely copy all information on use of artillery from military maps to analytic maps for parallel analysis, in order to make easier parallel analysis and data linking with other mine indicators.

Artillery action plan:

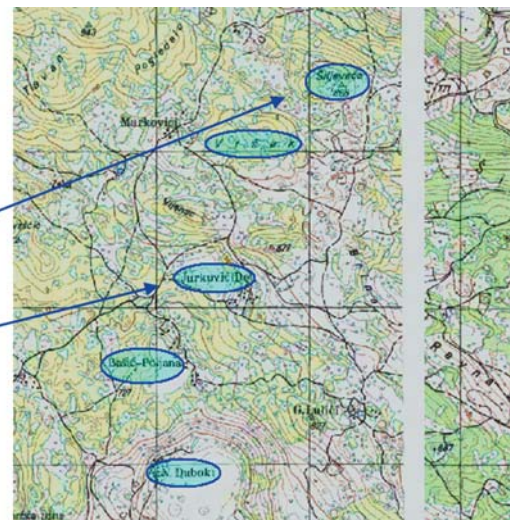
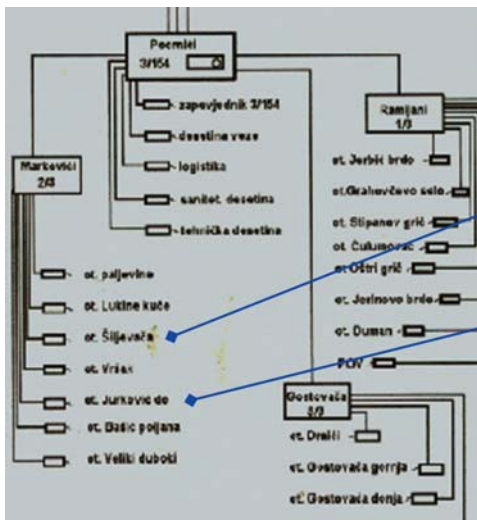
a) Artillery tasks

ZADAĆA	PAJLJBA BR.
Neutralizirati vodnu opornu točku u području Tromede	KP 21, KP 22
Ostvariti paljbe u području s. Štampari, KP 231, s. Grabac KP 231,	
Neutralizirati vodne oporne točke u području s. Svilari KP 25, Veljun KP 30, Rudine KP 28	
Neutralizirati neprijateljske MR bitnice u području s. Svilari- KP 24, s. Tučari KP 29,	
Sprječiti protu napad neprijatelja iz smjera s. Turjanski - s. Mašići Budžak- Drage. Iz smjera Čanak- Ramijani ostvarujući paljbe:	KP 234, KP 235, KP 233, KP 31, KP 33, KP 237, KP 32
Neutralizirati neprijateljsku	

b) Cartographic display of fired upon locations No. - pic.2.6.4.1



Display of data use in wire signals organisation and determination of resistance points in unit – sl.2.6.5.1



Information on artillery lay-out should cohere with some of the already known information on enemy units lay-out and with artillery targets and possible zones of mine-explosive obstacles.

If based on previous analysis, relevant mine indicators in the area are not determined, based on artillery lay-out, further research and mining assessment is required.

**2.6.5 Information on signals organisation** is shown on military map using prescribed tactical symbols according to type of signals and locations, or command posts with signals organised for them.

It is necessary, for research purposes to find out links between final signals stations, unit commander and firing positions. These positions can reveal organisational structure of the unit and/or specified defence points with mine-explosive obstacles.

Discovered locations, which are covered with specified type of signals (wire, radio, and courier), represent available station positions, and should cohere with some already known information on mine-explosive obstacles.

In lack of other information on mine-explosive obstacles, information on signals organisation can be very useful in research of mine-explosive obstacles, using discovered signals locations that can be potential zones of mine-explosive obstacles.

## **2.7 Terrain analysis**

Terrain, with all landscape characteristics, hydrography, vegetation, towns and villages, roads, economic objects and other natural and artificial artefacts, has a great impact on execution of combat activities, and hence, on mine-explosive obstacles, too.

Combat characteristics of terrain are studied and assessed, using all analytic preparation tasks, in function of organisation of offensive-defensive activities and mine-explosive obstacles.

Topographic- tactical characteristics of the terrain are studied parallel with combat layout and units tasks and their reciprocal connections and conditions. Terrain is assessed for the attacker and defender in order to correctly estimate attack directions, and mine-explosive obstacles can be placed according to attack directions.

Studying and assessment of terrain is carried-out in analytic preparation using topographic maps, aerial ortho-photo layers and other available data found in documents.

In lack of other information on mine-explosive obstacles, analysis of terrain and its characteristics can be primary information in assessment of mine-explosive obstacles.

Using terrain analysis in combat activities zone, it is necessary to determine:

- Terrain category: mixed, hills, mountains, plains, forests, karsts, swamps etc.
- Terrain passability based on landscape characteristics, developmental state of roads, and number of natural intersections (rivers, canals, swamps, steep slopes, gullies, abysses etc), which can harden and preclude movement and use of combat technology.



## General indicators for assessment of terrain passability

Landscape	Basic topographic characteristics of landscape			Basic tactical characteristics of landscape
	Absolute altitude	Altitude difference	Prevailing slope	
Plains -hills	Up to 200 m	Up to 50 m	Up to 5°	Easily passable in all directions, possible use if heaviest military vehicles, somewhat difficult concealment
Hills-mountains	Up to 500 m	Up to 200 m	5° – 10°	Good passability with exception of specified routes, easier concealment and protection, very good conditions for setting up firing system
Low mountains	500 – 1000 m	Up to 500 m	10° – 15°	Somewhat difficult use of military vehicles, significantly easier concealment and protection, favourable conditions for setting up firing system.
Medium mountains	1000 – 2000 m	Up to 1000 m	15° – 20°	Use of military vehicles possible only on specified routes, very good conditions for concealment and protection.
High mountains	More than 2000 m	More than 1000 m	More than 20°	Limited passability, use of heavier military vehicles almost impossible, very good conditions for concealment and protection, possible slides and avalanches.

Source: Croatian military college "Petar Zrinski" Military topography

## Possibility to surmount terrain slopes

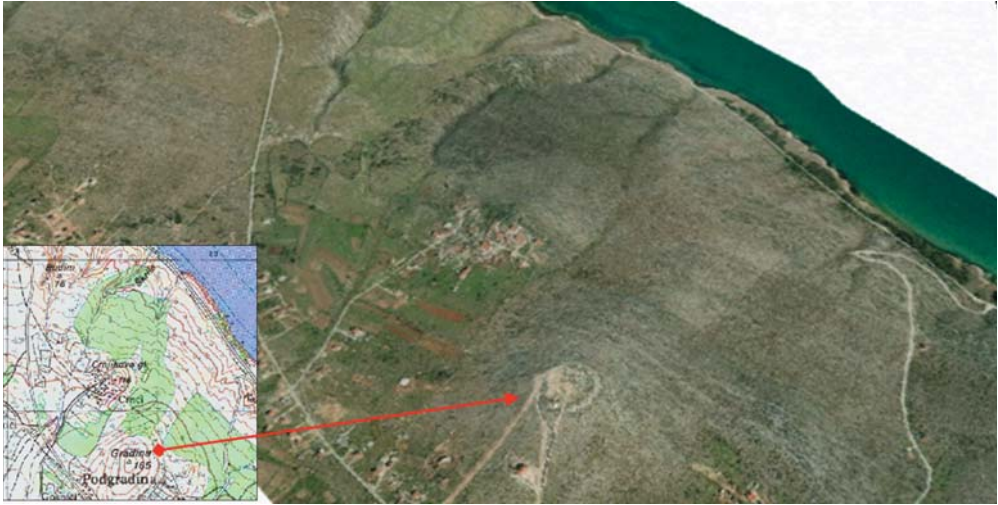
Terrain slope	Surmountable slopes on dry and hard soil
Up to 10°	Goods vehicles with trailer
10° - 20°	Off road and goods vehicles without trailer
20° - 30°	Tracked vehicles and transport animals
30° - 40°	Tanks and self-driven weapons up to 35°, on shorter distances up to 40°.
40° - 60°	Men, but holding onto ground and vegetation
More than 60°	Trained men with special equipment

Source: Croatian military college "Petar Zrinski" Military topography

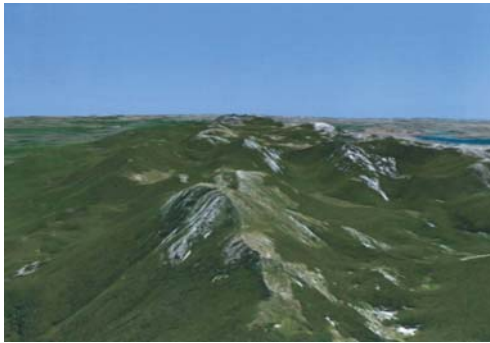
It is necessary to research natural barriers, using terrain analysis, as a basis in defence organisation that does not require obstacles, and thus they represent mine absence indicators.

These are primarily extremely steep slopes, rivers, lakes, swamps, abysses and other impassable terrain objects with assessment that according to the ways of warfare in this area there was not any obstacles placed.

Posedarje (Gradina tt 165): terrain conditions on frontal defence part (DOF2 3D) – pic.2.7.1



Natural barriers – assesment of mine absence – pic.2.7.2



Velebit Malovan: mountainous steep slopes



Kopačevo – Nature Park: lakes and swamps

Other – passable spaces for combat resources and/or infantry that we focus-on in our research of mine-explosive obstacles will be easier to notice if we define mine absence indicators

## 2.8 Publications analysis

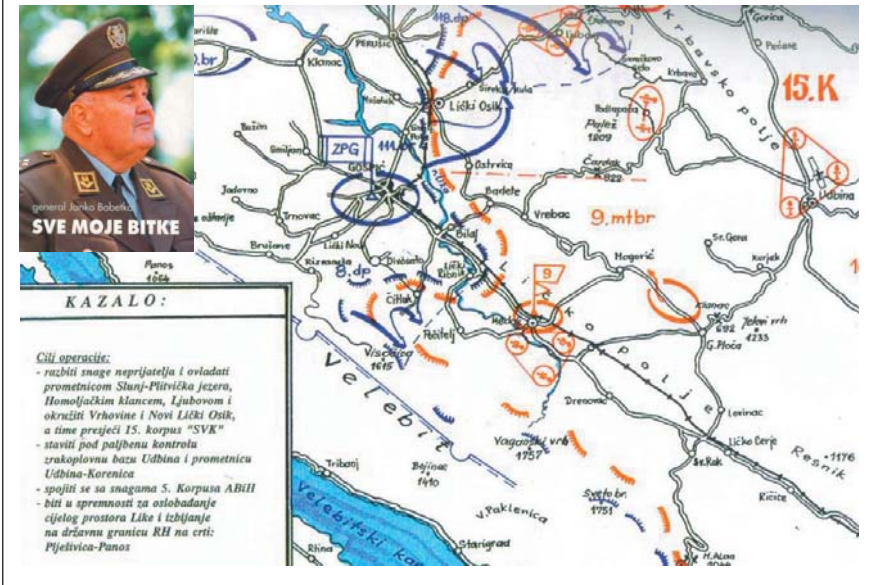
Information from published historical and other sources can be very useful in research of mine-explosive obstacles.

It is necessary, using analytic preparation and continuous following of published texts, to find-out useful information that can be linked to available data or that can, even, be a starting information for discovering to us unknown mine threat areas.

In lack of original information on mine-explosive obstacles, we can find following types of analytically useful data using publications:

- Chronology of military activities with defence lines movement,
- Units lay-out and combat stations,
- Units activities regarding engineering protection of combat activities,
- Locations of mine presence using mine incidents that have occurred during war,
- Persons – members of units can be use as contacts for data collection regarding mine situation, and
- Other military-political indicators that had an impact to mine-explosive obstacles.

Offensive operation „Oluja (Storm) 3” ZP Gospić area (detail)



*"In intervention of operative-tactical, direction Gospić-Medak-Gračac" the enemy, due to importance of the route, in right zone, including V. Humac (tt554), left: including s. Ostrovica, .... has engaged 9th mtbr as a strongest unit of 15th corps. It was reinforced with 65% of men. Defence with 2/9. mtbr and 3/9. mtbr is carried out towards forces ZP "Gospić", and with forces 1/9.in wider zone M. Alan towards forces ZP "Split". ... 3/9. mtbr with ZM u s. Vrebač (school) defence is carried out in zone Rodaica-Brda (tt 585) – Jajića Vrh (tt 727), by depth Karaula (tt 636). .....*



**Military provenance documents of "Republike Srpske Krajine (Republic of Serbian Krajina) "**

(Source: Republic of Croatia and Fatherland war – documents. Book 7)

*"Defence organisation of Velebit (05/04/1993) ...defence of mountain Velebit is to be organised with 2nd lč and 4th lč and VMB-82 mm as follows: 4th lč with VMB82 mm takes and defends zone: K. 1118, K. 826, Ošćenica with task: determined defence with mass obstacles and complete fortification with ..... support to objects Ošćenica and Golić prevent enemy drive through regimental zone. ...2nd lč takes and defends zone: Strašilovac, Bužonjkin vrh, Čaber.... .Simultaneously to be ready for orders execution on routes: Čaber – Tulove grede".*

"Engineers unit has yesterday afternoon removed antipersonnel bouncing mines on Tulove grede."

"Daily report (21/02/1992): Road between school in Vrana and Umac and byway from Umac to village Pupovci, was mined in order to stop armoured vehicles."



### Farewell battles of "Army of Republic Serbian Krajina"

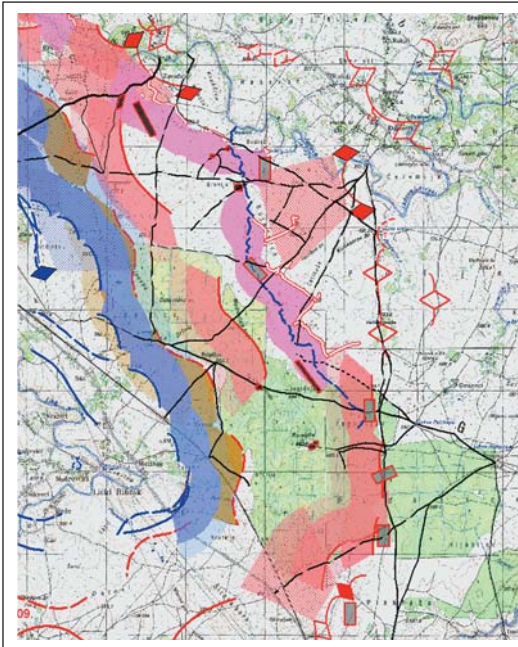
(source: M.Sc. Milisav Sekulić "Knin has fallen in Belgrade")

18th brigade:" .. 1st regiment of 3rd battalion in zone Pavenke, ... at defence junction of 2nd and 3rd battalion (route Čardak – Prikićev grič) and at junction of 2nd and 3rd battalion (route Vujatovo brdo – Karula). Positive fact is presence of Karula in secrecy, which has neutralised enemy's intention to cut off Teslingrad from Ljubova. .... brigade was supplemented with food and ammunition for surrounded battle (6 smaller warehouses were prepared). ... Command post in the village Bunić. Air-bombardment of Plješivica and Čelavac. ... There were no requests to defend positions by depth. ..."

## 2.9 Analytic assessment of mine suspected areas

In the first part of the analytic preparation we have examined all contents of all available data, and we have assessed their reliability for further use in elaboration of Analytic assessment of mine suspected areas.

In elaboration of analytic assessment of mine suspected area, final linking of various types of data is conducted, and their functional links are determined and reciprocal dependencies in the defence system and they reveal additional indicators in regard to mine-explosive obstacles.



Schema of linking data available in the system

Available information: mutual lay-out, lines movement, information

In order to more easily perceive causal-consequential connections using data linking, it is necessary to determine homogenous territorial parts in respect to execution of military activities, like station areas of battalions and regiments. If there is not such a possibility to define spatial frame of research, land objects that determine specific way of execution of offensive-defensive activities are taken into account (defence of settlement, river areas, routs passable by tanks, notches...)

Also, it is very important to stress-out that data should be linked according to sequence of military activities, and time of occurrence, in order to avoid obscurities and wrong interpretation, due to battle positions and lines movement or occupation of defence positions by the enemy.

Data linking should be done gradually and attentively, paying respect to facts that confirm specified state or guide us to other possibilities of executed mine-explosive obstacles, according to combat lay-out of units, terrain conditions and/or military importance of the area.

Procedures and work sequence in mutual data linking is adapted to available types and quantity of data, manner of military activities and other warfare conditions in specified area. The goal of all previously mentioned is to obtain clear indicators that correlate to mine-explosive obstacle.

For example, in the areas where we do not have mining records, main activity in data linking is directed to determination of connection between defence lines, terrain conditions and organisational principles of firing system.

In case of dilemma and obscurity obtained by data linking procedures with possible complicated situations, it is necessary to re-examine previous analysis and assessment, and set requirements for checking and collection of specified additional data.

Using analytic assessment, objectively possible indicators of current MSA state are determined, and in order to create a starting background for further data collection or execution of other mine action activities in analytically researched area.

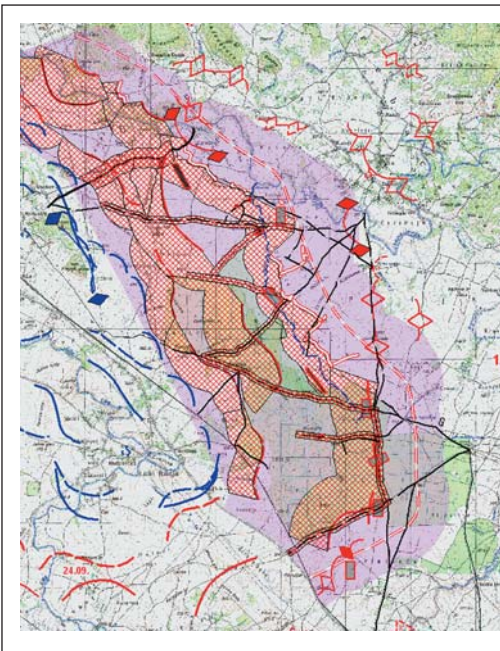
## **2.9.1 Presentation of mine suspected area assessment**

Analytic assessment of mine suspected area is a final document of total analytic work, and it presents indicators of MSA assessment and requirements for data collection.

### **2.9.1.1 Indicators of MSA assessment**

Three groups constitute indicators of MSA according to assessment:

- **Available information** used for analytic assessment of MSA.
- **Estimated mined areas and buildings.** By mines areas we understand areas with assessment that there are mine-explosive obstacles placed, according to combat activities content, regardless whether in this phase of research (analytic preparation phase) these areas are still mine contaminated.
- **Estimated mine suspected areas and buildings.** By mine suspected areas we understand areas for which we did not define, reliable and/or precise mine indicators using analytic work,, but according to lay-out of units, positions' movements and warfare concept in the area there is justifiable doubt on presence of mine-explosive obstacles in this area



Analytic map of mine suspected area assessment (detail) - pic.2.9.1.1.1

As available data, that have led to analytic assessment of MSA are following:

- **positions of mine-explosive obstacles in polygon display:** known mine-explosive obstacles, obstacles in assumed borders, obstacles positions from military maps that have not been confirmed through analytic data linking
- **positions of military demined mine-explosive obstacles in polygon display:** positions of demined obstacles, assumed positions of demined obstacles, positions of partially demined obstacles, military demined obstacles positions from military maps that have not been confirmed through analytic data linking
- **mine incidents positions:** precise positions, approximate positions
- **found mines positions:** precise positions, approximate positions, estimated borders of mine-explosive obstacles according to information on found mines
- **positions of detected mines in humanitarian demining projects:** precise mine positions, borders of known obstacle according to detected mines, borders of unknown obstacle according to detected mines
- **fortification obstacles:** types and borders of anti-personnel and anti-tank obstacles
- **combat lay-out of units:** defence zones with responsibilities, defence lines, movement lines, positions of fortification firing objects by type and purpose (trenches-traffic roads, shelters, bunkers, tank stations, artillery stations,...), command posts and scouting positions, travel network for units within line of defence, passable routes for armoured forces in the zone of mutual lay-out of units in conflict, names of units,...
- **natural barriers with assessment of mine absence:** borders of natural barriers.

Assessment indicators of MSA state are shown on the map (or more maps in order to ensure information clarity) with precise drawing of available data and new data reached by analytic preparation. Important assessment indicators are presented descriptively and in table with submission of demonstrative data, on which assessment was elaborated.

For the purpose of clarity and understanding of MSA state, to present the Assessment, it is necessary to use maps with larger scale, and descriptive indicators should be given according to names on the map or additional polygon and numerical mark of smaller described areas.

Analytic assessments of mine suspected areas that are elaborated after war military activities as the first assessments can be important in initial strategic assessment of local community mine vulnerability and way of resolving mine problem. When proportions of mine suspected areas are large, data collection for more precise assessment of MSA will last longer, thus in those cases, analytic assessment can be used for MSA marking in the field, informing and education of population about mine threat

Speaking of mine threat, mine suspected areas are equally dangerous as mined areas until they are deemed not mined or all mines have been removed from the area. In order to avoid eventual calculations on mine situation, and for purposes of population informing, it is necessary to use denomination *mined areas* rather than *mine suspected areas*.

### **2.9.1.2 Requirements for data collection**

Using carried-out research, we have determined that it is possible to improve assessment of MSA state by having certain additional data. Missing data required for more objective assessment of MSA state is shaped through Requirements for data collection

Presentation of requirements has to be, in content, understandable and complete, since:

- collection of individual data can be done using various methods or
- data will be collected by persons that did not participate in elaboration of analytic background or
- data collection will be carried out in a longer period of time, etc.

Collected data will be built in database and linked to previous achievements of analytic research of MSA. Hence, it is logical that they have a link to results of the analytic preparation from which they were created.

Probably other valuable information will be obtained by data collection according to set requirements, although this information is not a part of requirement and/or are not related to topic area, but to wider region.

This information has to be recorded in the report on collected data as additional information. Additional information that has special value is the one whose status can change with time, since information deteriorates and can be lost (MEO information, areas used during war or are currently used, persons that know mine situation etc.).

When possibilities to collect original data are exhausted, requirements will direct to data collection on mine indicators that appear within organisation and execution of offensive-defensive activities in the analytic assessment area.

### 3. GENERAL AND SPECIAL REQUIREMENTS FOR AIRBORNE SURVEY

Airborne survey as a data collection method without entering mine suspected area (without application of demining and technical survey methods) is especially applicable in the initial phase of MSA definition, or when mine suspected areas are more presented in respect to category of areas for demining.

Due to its capabilities, airborne survey is a rational method for data collection in shorter period of time and in spatial depth of mine suspected areas. On hard terrains and pathless areas, classic field survey methods are not efficient or they are not usable.

Requirements can be set to airborne survey to find (or detect) specified land objects and executed works on land, that are mine presence or mine absence indicators. Generally, requirements can refer to detection of the following information:

- **finding land objects or marks** in order to determine positions of mine-explosive obstacles
- **finding objects and/or works on engineering systems for execution of combat:** trenches and traffic roads, firing positions, artillery positions, shelters, new roads built for manoeuvring in the zone of combat positions, executed demolitions, presence of other fortification obstacles on the roads and narrow-channelled passes
- **finding specific land objects that are used in military activities and are obstacle topic:** roads, bridges, serpentine, notches, gullies, mountain notches, dry-stone walls, banks, gaps in banks and roads, areas on the forest edges, glades, water springs, improvised dwellings
- **finding remains of military technology and other equipment:** vehicles, weapons, wrapping materials
- **finding natural barriers that are by nature an obstacle:** rocky mountainous areas with extreme slopes, areas under water
- **finding areas and buildings in assessed MSA that are being used:** agricultural and forest areas, infrastructure objects, roads

Based on analytic assessment of mine suspected area or a current state of MSA it is necessary to specify requirements into general and special requirements, in order to find specified land objects and executed works on the ground using airborne survey.

Finding and positioning of various indicators, reached by analytic preparation are required by **general requirements**. These indicators are general ones and they may be for example: general requirement for finding forest notches and roads in separation zone, general requirement for finding of cultivated areas, general requirement for finding rebuilt infrastructure objects, etc.

There could be a greater number of general requirements when available data is scarce and analytic assessment has not given clearer conception on military activities. In these cases, majority of requirements can relate to findings in the whole area that is to be airborne surveyed.

Finding and positioning of strong mine absence and mine presence indicators is required by **special requirements**. Their presence in the survey area was established by Analytic preparation. Strong indicators enable more precise definition of mined areas, reduction of mine suspected areas, and total MSA state will be presented more objectively in respect to starting Assessment.

Narrower areas or land objects are specified in special requirements, and there are indicators to be found, such as:



- Fortification objects in defence units' lay-out,
- Objects that are benchmarking points for determination of mine-explosive obstacles positions
- Characteristic landscape shapes where there is most probably obstacle,
- Presence of natural barriers as mine absence areas,
- Presence of used areas

Special requirements are given in easily viewed table, and following information should be apparent:

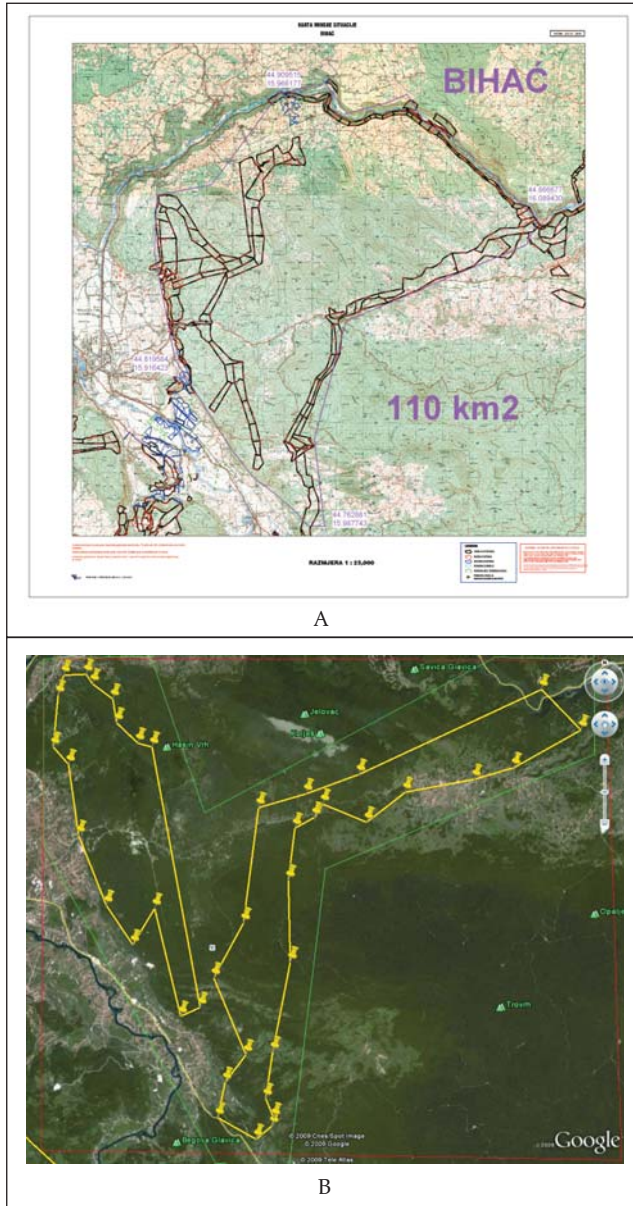
- Area where findings are expected as required,
- Precise data that has to be collected during airborne survey and
- Indicators relating to the requirement that were obtained by analytic preparation

### Special requirements for airborne survey (model example)

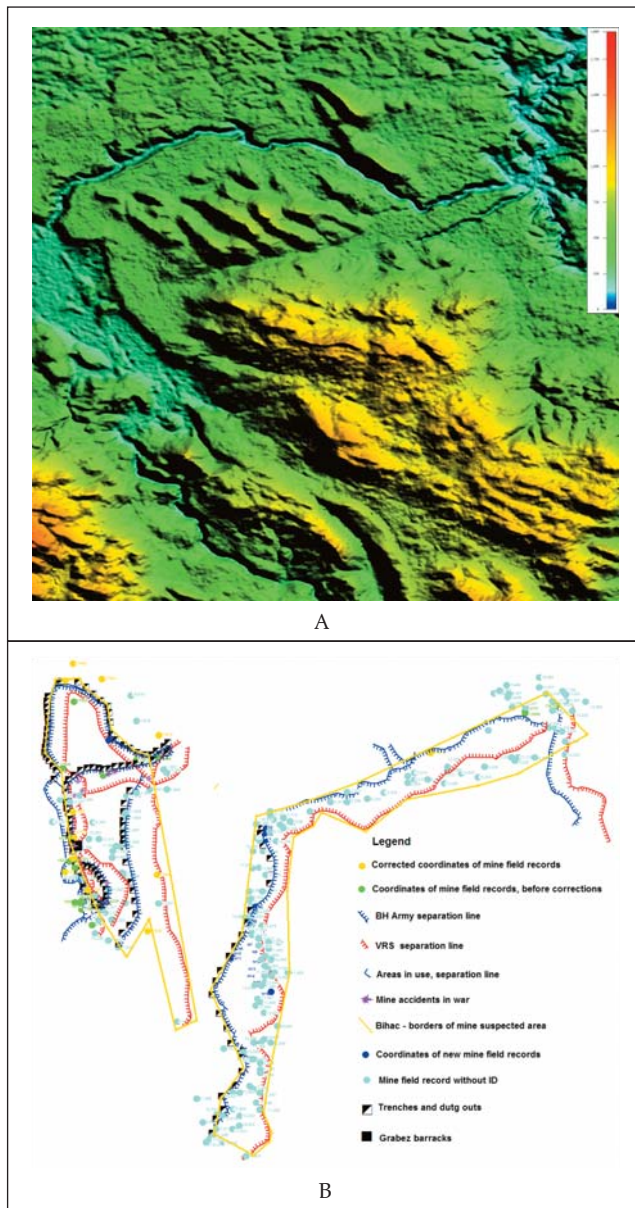
Area/ Area mark	Data to be collected (land objects according to map 1:25000, mark: 419,420,469, 470)	State according to analytic assessment
Varošina (tt538), Vujatovo brdo, Gluntuša (tt683)	<b>Find positions of firing stations in combat lay-out "ASK" in line:</b> north slopes of Varošina (tt538) – Ograda – bunker next to the main road (south) – structural object off byway to – north and east slopes of Vujatovo brdo. <b>- Find positions of firing stations "ASK" and CA in Gluntuše area</b> (tt 683) (movement of lines of conflicted parties) <b>- Find tank passability of the field in direction:</b> Gluntuša (tt683) (east) – depression of the terrain (west) - Vujatovo brdo	Item 2.1 MEO record analysis. There are shelters and bunkers in trench system on Vujatovo brdo, built on surface and semi-buried with wood and stone construction
Forest region of Rodaice	<b>Find positions of firing stations "ASK"</b> <b>- in the west zone of the forest:</b> Grofija – Gorice - Počadžbina (k580) - Tromeda (tt586) and Stilinovka; <b>- in the middle forest region:</b> Bucačište (tt587) – Jagodnjak (k584) – Mudrovčiča brdo (k584) – Dukovčevo brdo, and on forest mounts and glades <b>- in the east part of the forest:</b> west and/or east of forest pathway in direction Plantaža – Jagodnjak tt588)	According to display on analytic assessment map. Information on defence lines obtained from military maps was deemed as imprecise.
	<b>Find characteristics of the forest area:</b> <b>- forest passability</b> for armoured units and infantry: forest paths and notches that are not registered by analytic assessment, places of fallen trees on roads and notches, waterways, bridges, stony areas, depressions of the terrain. <b>- presence of structural objects:</b> dwellings (forest houses), improvised dwellings and/or shelters scouting stations <b>- presence of burnt areas and felling</b>	Scarce pine forest with openings, cut with forest pathways and notches
Road Bilaj - Barlete	<b>Check passability of the north road region in width of 200 m</b> on tank passable direction – section: settlement Babulj (east) – bridge on river Jadova	unknown
Stream Suvaja (east)	<b>Find positions of tank and artillery stations "ASK" and tracks of vehicle movement</b> between creek Suvaja and local pathway in section: forest region Rodaice – bridge on river Jadova	According to display on analytic assessment map, depth of defence
Settlements Zavode and Brdo	<b>Find areas and objects that are used</b> south of river Jadova in the area of settlements Zavode and Brdo (houses and infields, plough lands, meadows, local roads and pathways)	unknown

#### 4. QUANTITATIVE ANALYSIS OF THE MINE SUSPECTED AREA AND PLANNING OF THE AERIAL ACQUISITION MISSIONS

The quantitative analysis of the mine suspected area and the planning of the aerial acquisition missions is presented and illustrated from Fig. 4.1 to Fig. 4.5.



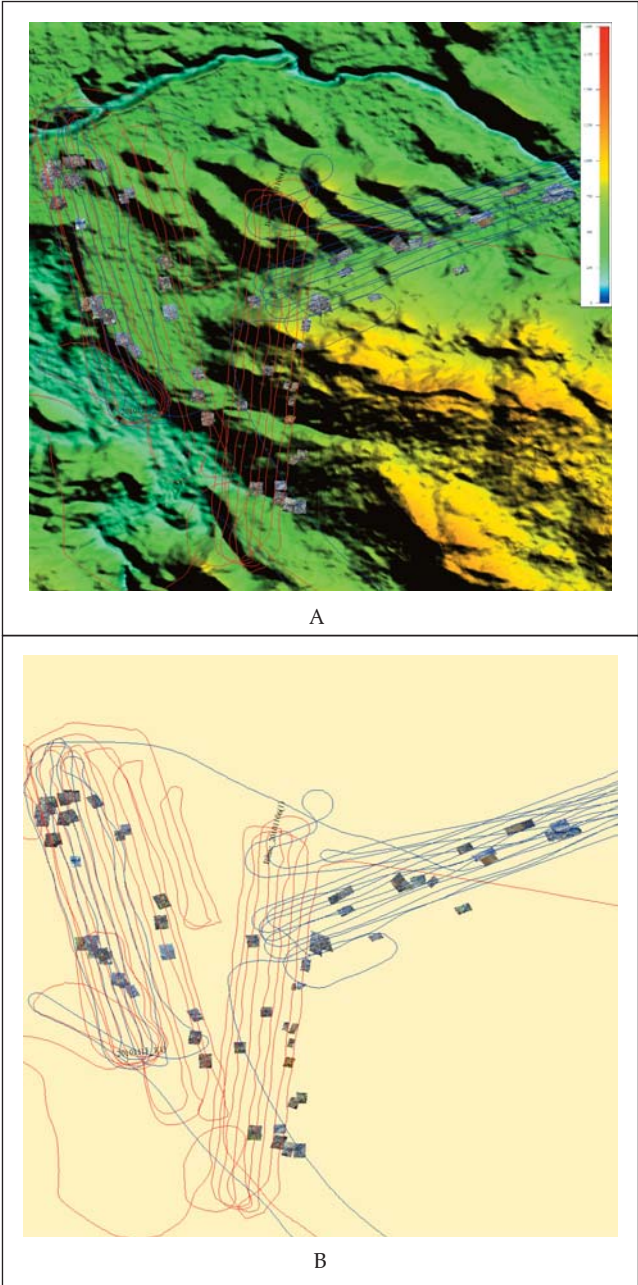
**Figure 4.1** A) Initial coarse requirement for aerial acquisition. B) Improved definition of the regions of interest (yellow lines) and the wider areas for aerial data acquisition (green lines).



**Figure 4.2.** A) The features of the relief influence the versions of the flight routes. The flights should provide similar ground resolving distance for the regions where are expected targets. B) The additional contextual information about the mine suspected area increases level of the understanding of the mine suspected area and its history. In the same time it can partially compensate the lack of the information from mine field records, Tab. 4.1.

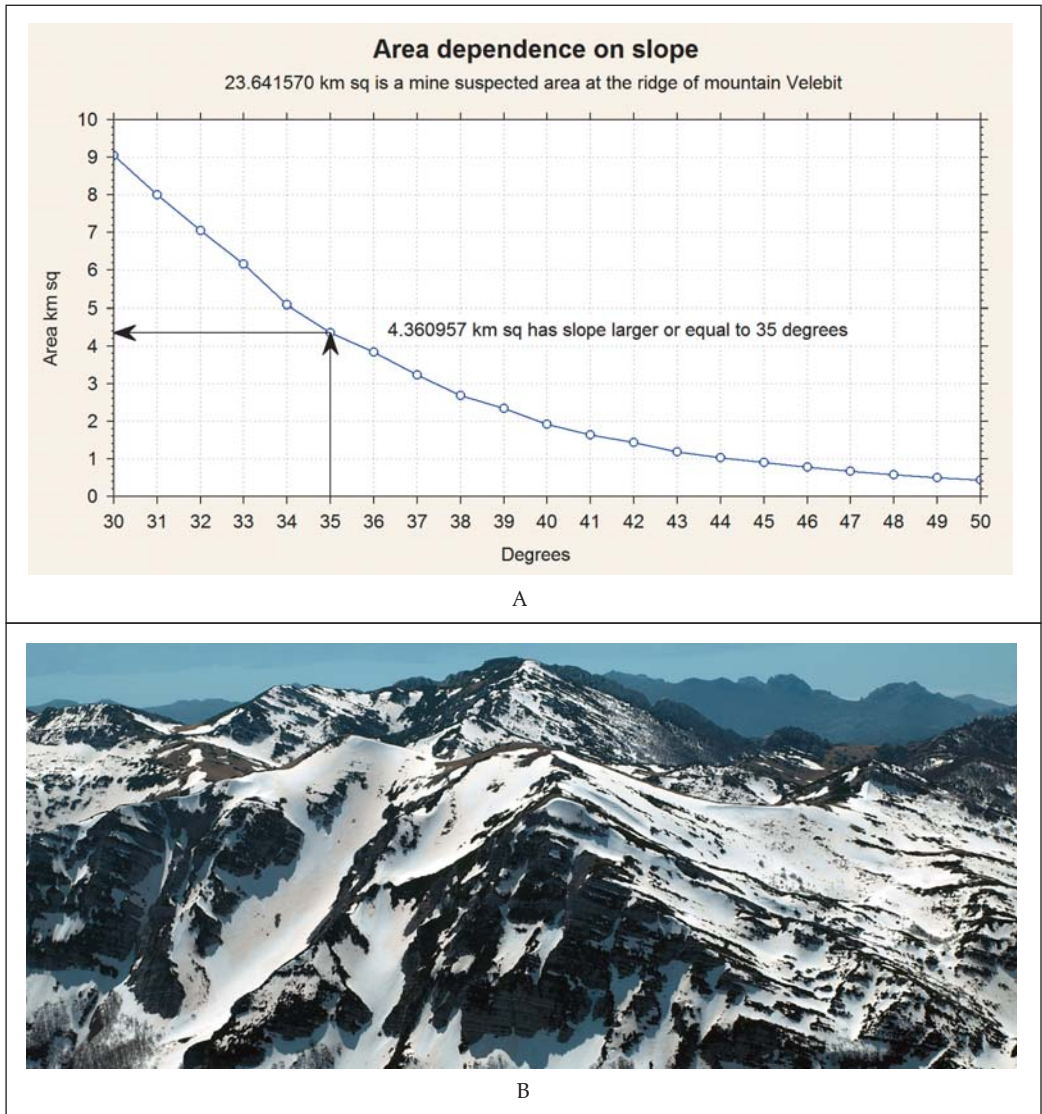
After the advancement of the understanding the mine suspected area, provided by actions shown in Fig. 4.2A and Fig. 4.2B the plans of the aerial missions can be matched to

the terrain and to the features of the targets which should be detected. The example of the finalized aerial imagery acquisition mission is shown on Fig. 4.3.



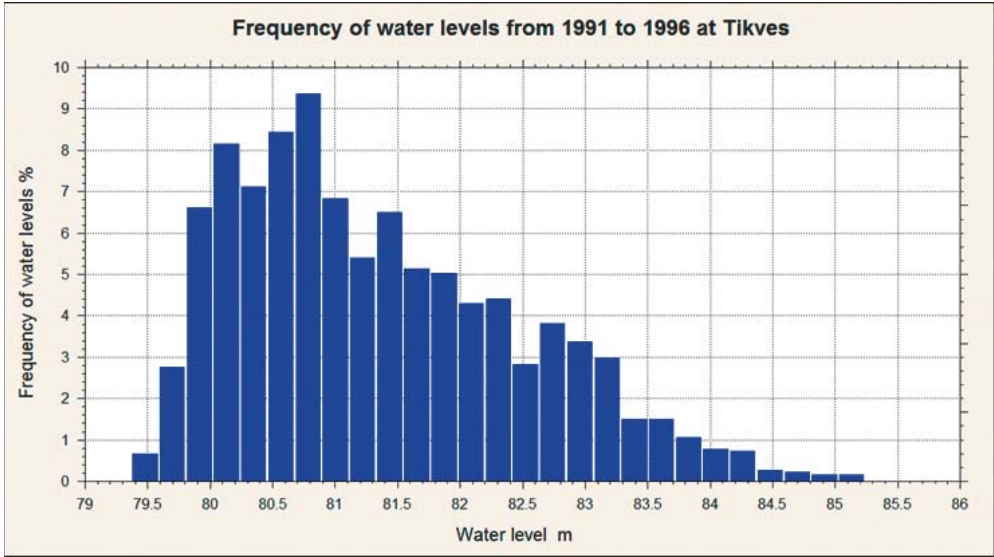
**Figure 4.3.** The example of the finalized aerial imagery acquisition missions. A) The locations of the geocoded images (grey patches), the flights routes (blue and red lines) shown over the digital elevation model. B) The locations of the geocoded images (grey patches), the flights routes (blue and red lines).

The analysis of the relief provides data about the slopes which are main factor that determines accessibility, the example is shown at Fig. 4.4 (slopes of the mountain Velebit, community Gospić, Croatia).



**Figure 4.4.** The analysis of the slopes of the relief of the mine suspected area of the mountain. A) Dependence of the area km<sup>2</sup> of the slopes on the slope angle in degrees. B) Part of the ridge of the mountain Velebit where slopes were calculated.

The totally different type and also drastic type of the terrain influence is the case of the large swamp areas that have changeable water level, example is shown at Fig. 4.5. The variations of the water level are the crucial information in this case.



A



B

Figure 4.5. Another drastic type of the terrain influence on the application of the AI DSS is the case of the large swamp areas. A) Frequency of the water levels. B) The satellite image at the Google Earth Pro site of the part of Kopački Rit swamp, community Bilje, near Osijek, Croatia.

Besides the terrain influence on the results of the AI DSS there are other influencing factors too. Among them the most important are the contextual information and data; example is shown at Fig. 4.2B and in Tab. 4.1. For the mine suspected area shown at Fig 4.1A (obtained from the mine action centre) were available only 51 mine field records (several of them were not usable), 177 mine field records are missing for this area. The expert estimates that the average precision of data in the existing mine field records needed for the locating the mine field is only 40%, Tab. 4.1. The described situation was hopeless and the chances to provide results by AI DSS were very low.

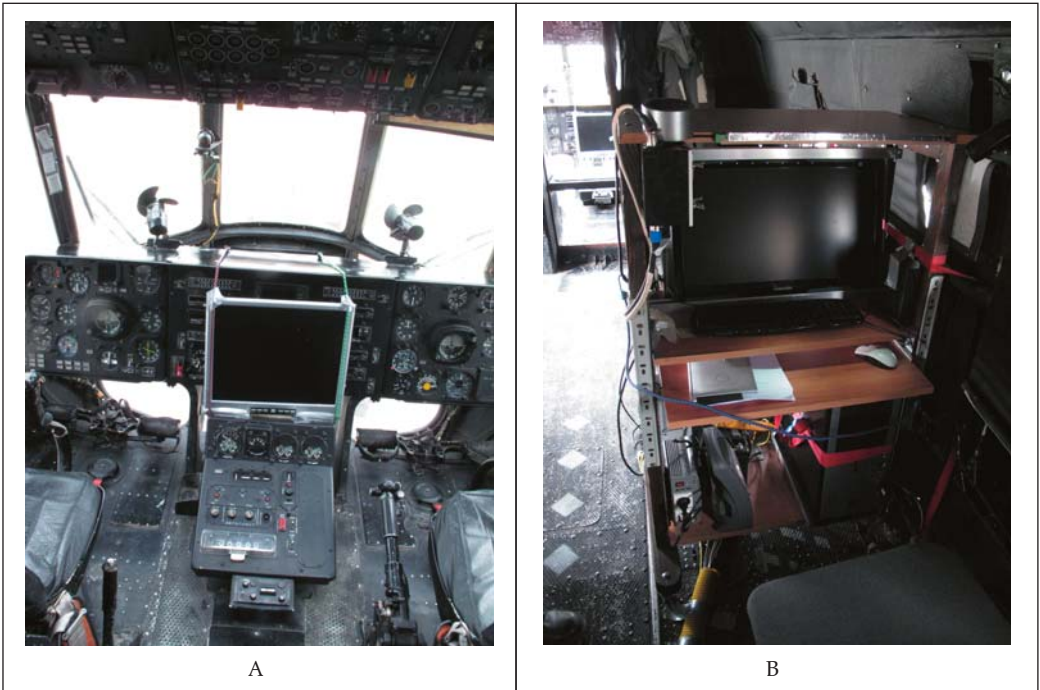
**Table 4.1.** The imperfections of the mine field records for the region of interest shown at Fig. 4.2B.

Number MFR analysed	MFR exist	MFR not exist	Average precision locating MFR on map	MFR unknown position number/percentage	
228	51	177	40 %	185	81%

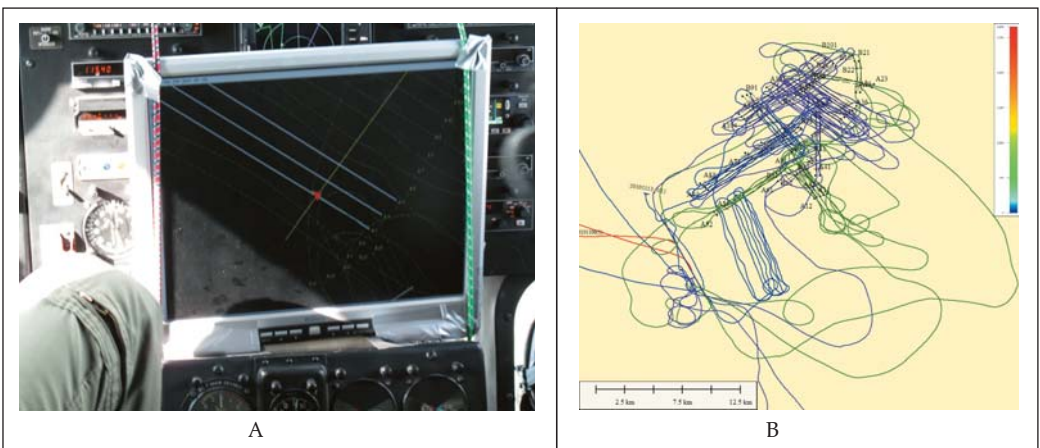
The contribution of the expert from the regional office, in the form of the contextual data and information given at Fig. 4.2B compensated the lack of the information and data in available mine field records and the very positive results were achieved.

## 5. AERIAL MULTISENSOR IMAGES ACQUISITION

The figures from Fig.5.1 to Fig. 5.4 show main parts of the control of the imagery acquisition flights.



**Figure 5.1.** A) The console for the control of the sensors and the acquisition units of the aerial multisensor system. B) The view of the cockpit, in the middle is the additional console for navigation during the imagery acquisition mission.



**Figure 5.2.** A) Pilot and co-pilot can select active routes and guide the helicopter between the allowed margins. B) A set of the routes of the several flights over the mountainous terrain.





## 6. PROCESSING AND THE INTERPRETATION OF THE AERIAL IMAGES

The processing and the interpretation of the aerial and satellite images is activity which starts with the visual, subjective triage after the delivery of the airborne acquired imagery to the ground based processing and interpretation team of the AI DSS. After each aerial mission, the mined scene interpreters compare the acquisition plans and acquired imagery and generate requirements for new acquisition or for the repetition of the parts of the imagery acquisition. In the cooperation with the expert from the regional office which is responsible for the considered mine suspected area, the interpreters estimate the usability of the acquired imagery. After the approval that the acquired images are usable, the interpreters do the subjective analysis of the images using all kinds of the data and information. This part of the subjective interpretation is supported by different computerised enhancement techniques that should assist to achieve higher probability and the highest possible confidence of the detection. The interpretation reports define the images that contain the indicators of mine presence (IMP) and the indicators of mine absence (IMA). The selected images, that contain IMA and/or IMP are geocoded, their image quality measures are calculated. The next phase is the extraction of the sub images that contain the IMA and/or the IMP. Each IMA, IMP is vectorised as well as their nearest neighbourhood and vectors are delivered to the interpreter who will calculate the danger map. To get the feeling about the detection of the indicators follow several images with the examples of the most important IMP.



**Figure 6.1.** The trenches in the mine suspected area of wetland Kopački Rit, community Bilje Croatia detected on the aerial image acquired in 2009. (Figure6.1\_B LJ\_IMG\_7766\_rovovi\_d.tif)



**Figure 6.2.** The trenches at the edges of the forest in the mine suspected area near Bihać, Bosnia and Herzegovina, detected on the aerial image acquired in 2010. (Figure6.2\_B\_trenches\_forest\_edge1450.tif)



**Figure 6.3.** The system of old bunkers, trenches and new shelters in a rocky terrain of the mountain Velež, near Mostar, in Herzegovina. (Figure6.3\_M\_0338\_A\_b.tif).



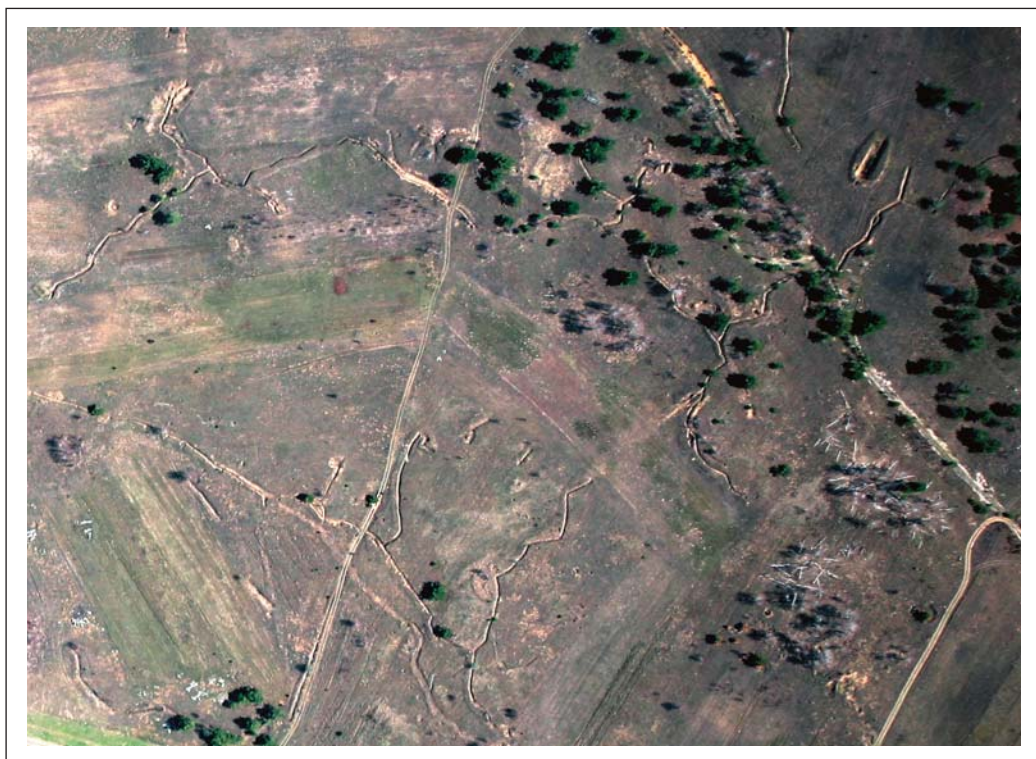
**Figure 6.4.** The set of shelters in a rocky terrain of the mountain Velež, near Mostar, in Herzegovina. (Figure 6.4\_M\_0338\_B\_b.tif)



**Figure 6.5.** The small circular and larger rectangular shelters on the rocky terrain of the mountain Velež, near Mostar, in Herzegovina. (Figure 6.5\_M\_0042\_A\_b.tif).



**Figure 6.6.** The shelters made in the soil on the open terrain in the mine suspected area near Bihać, Bosnia and Herzegovina, detected on the aerial image acquired in 2010.  
(Figure 6.6\_B\_shelters\_0364\_d.tif).



**Figure 6.7.** The abundance of the trenches, shelters for soldiers, shelters for tank. Detected on the aerial image from mine suspected area in community Gospić, Croatia, 2009.  
(Figure 6.7\_G\_IMG\_0834\_ukopani\_zakloni\_rovovi\_d.tif)

## 7. FORMALISATION OF EXPERT KNOWLEDGE, CONTEXTUAL INFORMATION AND DATA

The Decision Support System (DSS) in humanitarian demining was designed for analysing and processing all accessible compatible data, information and expert knowledge about mined scene. After collecting all accessible data about some particular scene, it is necessary to put all that data in a comparable relationship. It is mandatory for using all indicator impacts on the scene for getting final results (thematic images). DSS is a methodological tool for processing multi-spectral and hyper-spectral data (images of the scene), contextual data and expert knowledge. The final results of that processing are images that show impacts of all indicators on the some particular scene. Those images were made for helping decision makers and reacting managers at decision making.

### 7.1 Concept of the system

The basic concept of Decision Support System (DSS) in humanitarian demining and its interactions with environment is displayed by scheme on figure 1. The main activities in DSS construction are:

- determining list of indicator,
- input data collection,
- data pre-processing,
- validation of input data,
- data processing,
- formalisation of expert knowledge,
- data fusion,
- thematic images (discrete and continuous) generation,
- validation of the results.

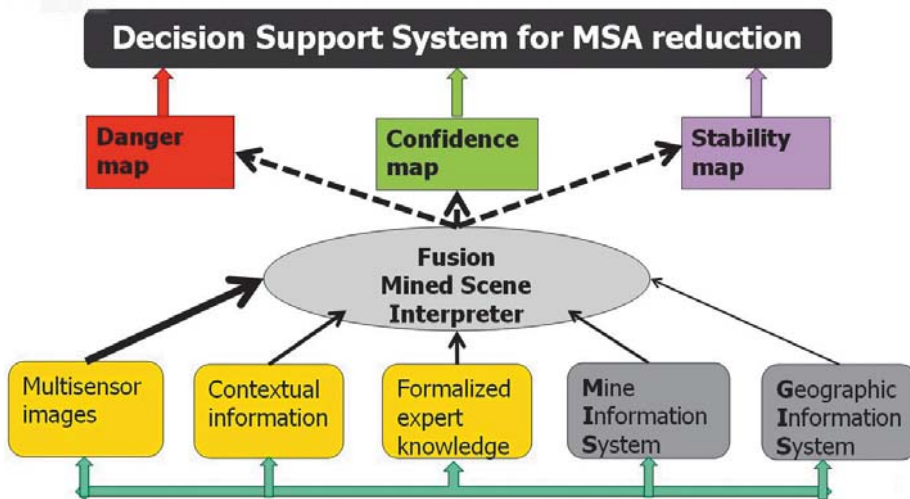


Figure 1. Concept of DSS in humanitarian demining and its interactions with environment.

The operator (the mined scene interpreter) (Vuletic, Krtalic, 2005) must have specific knowledge, skills and knowledge about particular scenes (mined scene) for managing this system. For that reason the interpreter of the mine scene must closely cooperate with demining experts. The list of the objects is made on the basis of this collaboration. That objects are indicators (Yvinec et al, 2005), and those indicators need to be detected and marked on the multi-sensor images. This can be done automatically or interactively depending of the indicator. Indicators in humanitarian demining are divided in two categories: indicators of mine absence (IMA) and indicators of mine presence (IMP). Objects like agricultural land or asphalt road in use lead to the conclusion that this area is free of mines. On the contrary, objects like trenches, bunkers, abandoned agricultural land and minefields records lead to the conclusion that mines are present somewhere in that area. The detection and marking of IMA and IMP need to be done on multi-sensor images. The determination of the position in space and the vectorising thereof are also mandatory for contextual data (minefield records, mines accidents). Furthermore, their impacts on other objects at the scene must be taken into account in data processing from the contextual data. For that reason the fuzzy logic is used, indicator impacts are displayed by membership function (Fig. 2) on the basis of information from experts in humanitarian demining (Tab. 1). Presumptions of experts for mine action serve as basis for the pondering of indicator impact on environment and the mutual impacts.

**Table 1** - Control points used to determine the shape of the membership function of some type of indicators.

Indicator	Risk starts at (m)	High risk from (m)	High risk to (m)	No risk beyond (m)
Agricultural areas that are no longer in use (IMP)	indicator	indicator	indicator	indicator
Bridges (incl. destroyed bridges) (IMP)	0	0	100	150
Confrontation zone from analytical assessment (IMP)	0	100	250	300
Damaged, destroyed houses (IMP)	0	0	50	50
Forest edges (IMP)	-10	0	10	20
Trenches and man-made embankments (IMP)	0	100	150	300

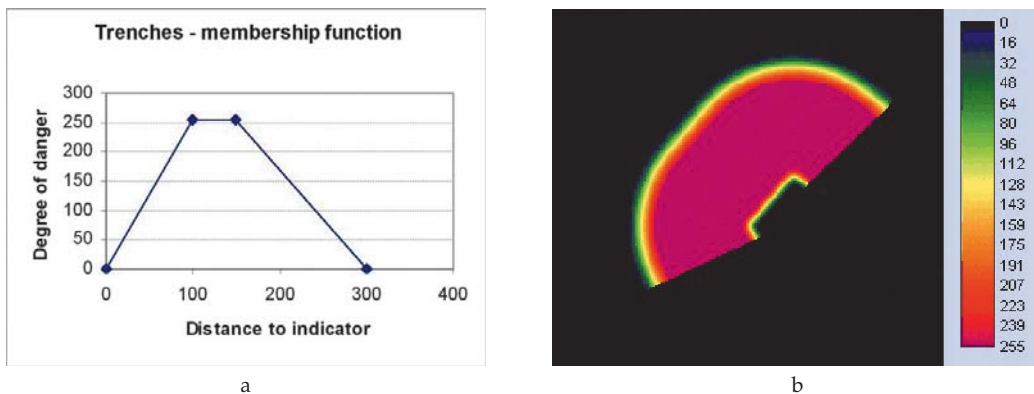


Figure 2 - Shape of the membership function for trenches: a) diagram and, b) raster of danger degree in 8 bit scale (from 0 to 255).

According to this information and expert knowledge, all indicator impacts on environment can be displayed.

## **8. FUSION, MULTI-CRITERIA AND MULTI-OBJECTIVE ANALYSIS AND PRODUCTION OF OUTPUTS**

The thematic images which display the interaction between all input data (danger maps and confidence maps) are made on the basis of that data processing. Before input data and information processing it is necessary to analyse the data and information and to define their characteristics (imperfections, redundancy and complementarities (Yvinec at all, 2005)) and levels (low – mostly original data, high – pre-processed data (Yvinec at all, 2005)). The decisions on the further actions make the decisions makers and reacting managers. The decision is made on the basis of the processing results of all input data. Products of DSS are also thematic images of confidence and stability of declaims on mentioned thematic images (danger maps and confidence maps). This system developed by the implementation of the generic methodology for support in decision making from the project *Space and airborne Mined Area Reduction Tools (SMART)* (EC-IST-SMART, 2001) funded by the European Commission. The aim of the SMART project was to provide end-users with safe, cost-efficient, innovative, validated and user friendly tools for monitoring of the environment and for the assistance to the decision makers and reacting managers in humanitarian demining. The results of DSS are using for helping in the reduction of MSA or reinforce of suspicion in MSA.

### **8.1. Input data**

Input images data for DSS can be all sources of multispectral, hyperspectral, thermal digital images, or radar images. The input data also can be geo-spatial data like aerial photogrammetric images, digital orthophoto (DOF - panchromatic or colour) and digital terrain models (DTM) if that exist. Geographic maps of different scales can also serve as input data for DSS. The other input data are specific contextual data about particular phenomenon which is analysed on the scene and based on expert knowledge. Ground truth data (data from the field) about particular scene are also input data. This data is used in data processing and validation of results of classification, data fusion and thematic layers.

### **8.2. Pre-processing and validation of all input data**

The purpose of data pre-processing is the detection and enhancement of indicators on input (multi-sensor) images. Only undoubtedly detected indicators can serve as inputs into the DSS system. Because of the fact that the aerial images acquisition system is a multi-sensor system, every sensor within has different resolution of the images. The precondition for the combination and data processing (classification, data fusion) of the information from those images is the registration of all input images regarding to one reference image (mostly image with the best ground resolution) (Krtalic, 2006). After that action all images have the same image resolution and they can be combined. The quality of the image registration should be known and taken into account in the assessment of the results. The quality assessment of overlapping of geodetics bases and multi-sensor images need to be done (Krtalic, Fiedler, 2006). Further more, an estimate of the reliability of all contextual data which are inputs for data fusion also need to be done. The source of contextual data must be determined before data processing.



### 8.3. Data processing and data fusion

The aim of data processing is to prepare all data for classification and data fusion, followed by production of thematic images. Classification and interactively interpretation of the scene are based on uncertain statements (*strictly divided of object on the scene is not possible and every statement of indicators must have level of confidence*). The purpose of the classification and interactively interpretation is to detect and separate indicators from other objects on the scene. All this actions are conducted based on fuzzy logic. Fuzzy logic is a mathematical approach to quantifying uncertain statements. The basic idea is that the truth value of the statement from strictly logical value *yes* or *no* be replaced by continuous range of values from zero to one [0...1], where 0 means *exactly no* and 1 means *exactly yes*. The output of a fuzzy classification system is a fuzzy classification, where the membership degree to each class, i.e. land use class, is given for each object. For a successful classification a deliberate choice of *membership function* (Definiens Professional, user guide) is crucial. This allows interpolation of expert knowledge into the system. The first aim of data fusion is to combine all results derived within DSS and from expert knowledge. The second aim is to produce thematic images with impacts of indicators on the scene and also impacts between indicators on the base of the fusion results.

#### 8.3.1. Thematic images (Danger maps)

Danger maps (Wolff, 2004) are synthetic documents designed to help the end-users in their decision-making process regarding MSA reduction. They are documents that combine the results yielded by detectors and classifiers, with added expert knowledge referring to the size of the area of influence of each indicator. For each IMP and IMA, detectors and classifiers were implemented to derive location, and confidence images. The *location images* are binary masks featuring the indicators, whereas the *confidence images* show the confidence value in the detection or classification result. Some location and confidence images came from other sources, like the MIS. Data fusion was performed when there was more than one result for a given indicator. After this process, a single location image and a single confidence image were available for each indicator (Wolff, 2004).

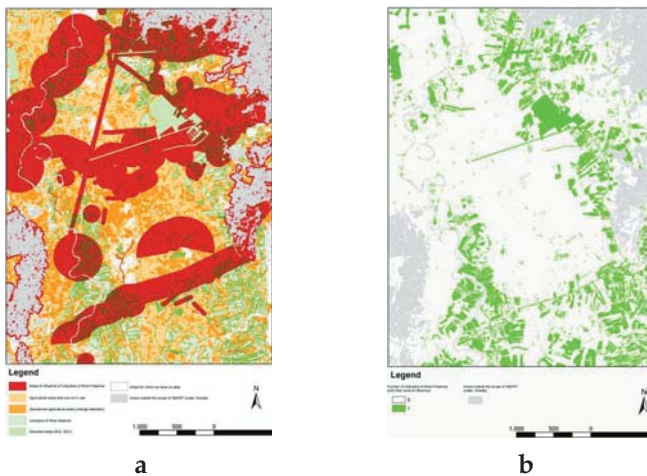


Figure 3. a) Discrete location map of IMP; b) Discrete location map of IMA

Danger maps were produced on the basis of location and confidence images. Two types of danger maps were defined, with the objective of providing the end-users with information that can help them make a decision about area reduction: *discrete danger maps* (Fig. 3a) and *continuous danger maps* (Fig. 3b) (Wolff, 2004). The discrete danger maps cover a complete scene and mainly feature the area of influence of all the indicators that were detected. They are documents that combine the results output by the detectors and classifiers, with added expert knowledge referring to the size of the area of influence of each indicator. Continuous danger maps cover a complete scene and feature more elements than discrete danger maps. They introduce more nuances and require additional expert knowledge.

#### **8.4. Validation of the results**

The results of the classification and thematic images should be evaluated for the purpose of testing the DSS efficiency. The validation of the results is done by confusion (error) matrix and its parameters (Congalton, Green, 1999). For this purpose good ground truth data of the scene and objects on it (collected from the field) are needed. They represent a reference data for comparison with the results derived from DSS. The parameters of the confusion matrix give analytical presentation of benefits of all DSS results (classification, thematic images). The benefits of the DSS results can be also presented with cost-effective analysis by comparison of assets needed for the proposal for reduction of MSA by regular survey and by methodology of DSS.



## 9. CONCLUSIONS

The Advanced Intelligence Decision Support System (AI DSS) is the mine action technology based on the airborne and space borne remote sensing for the assessment, reduction, inclusion and re-categorization of the mine suspected area. The AI DSS was developed and operationally implemented by Faculty of Geodesy University of Zagreb and CROMAC-Centre for Testing, Development and Training Ltd. (HCR-CTRO d.o.o.), Zagreb, Croatia, starting from the generic methodology of the European Commission's project SMART and our own development and advancement, supported by the Croatian Ministry of Science.

The AI DSS combines:

- a) Analytic assessments and derivation of the Statements of Operational Needs about the availability and quality of the data and information in the Mine Information System (MIS) and geographic information system (GIS) of the mine action centre.
- b) Airborne multi sensor imagery acquisition and usage of satellite imagery that provide new data, information and evidences about the state of the MSA (the indicators of mine presence and mine absence) with high accuracy and confidence. Use of the contextual information and the formalized experts' knowledge.
- c) The multilevel fusion and multi-criteria, multi-objective processing, interpretation and production of outputs: the danger map, the confidence map, the map of indicators of mine presence and mine absence, the map of conflicts between MIS and AI DSS outputs.

The application of the AI DSS technology starts in the mine action centre and the results of the whole process finish there, these are reasons for this publication. Its aim is to enable effective preparation of the analytic study and the derivation of the general and specific requirements for the information gathering about the mine suspected area where the AI DSS should be applied. Therefore the other contents about AI DSS technology are presented very briefly. The publication contains plenty of different examples related to AI DSS technology.

The experience of the former application of AI DSS in Croatia and Bosnia and Herzegovina approved benefits of this technology and this publication should support its further application.



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With its testing capacity (Test sites and equipment) and highly professional staff, the Center offers the following services:

- testing and certification of:
  - demining machines
  - mine detection dogs
  - metal detectors
  - personal protective equipment
  - prodders
- training on the use of metal detectors
- EOD training courses, levels 1 to 4
- training of work site managers, demining teams and monitoring personnel
- implementation of the decision support system for area reduction based on airborne survey
- implementation of research and development projects in the field of mine action
- verification and validation of demining and detection methodologies, technologies and equipment
- organizing workshops, conferences and other gatherings on the subject of mine action
- preparation for introducing quality management in demining companies as per ISO 9001:2000
- lease of test sites
- scientific and professional cooperation with national and international institutions.