NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

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RTO TECHNICAL REPORT **TR-SET-076**

Sensors for Urban Operations

(Les capteurs pour les opérations en zone urbaine)

Final Report of Task Group SET-076/RTG-044 MSE.

Published June 2009

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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List of Acronyms

C2	Command and Control
CBRNE	Chemical, Biological, Radiological, Nuclear and Explosive
ELINT	Electronics Intelligence
EO	Electro-Optic
ESM	Electronic Surveillance Measures
FOV	Field Of View
GPR	Ground Penetrating Radar
HumInt	Human Intelligence
IED	Improvised Explosive Device
LADAR	Laser Detection And Ranging
LOS	Line Of Sight
MCO	Major Combat Operations
MMW	Millimeter Wave
MOOTW	Military Operations Other Than War
NBC	Nuclear, Biological, and Chemical
NRT	Near Real Time
OSint	Open Source Intelligence
SAR	Synthetic Aperture Radar
SigInt	Signals Intelligence
TRL	Technology Readiness Level
TTW	Through The Wall
UAV	Unmanned Aerial Vehicle

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Sensors for Urban Operations

(RTO-TR-SET-076)

Executive Summary

SET-076 "Sensors for Urban Operations" task group was formed to examine what types of sensors were most useful in an urban context and to recommend research areas and collaborative trials. The team began their study in the fall of 2004. The Programme of Work was informed by work done by other groups: IST-046 "Command and Control Challenges for Urban Operations" and The Technical Cooperation Program (TTCP) AG-09 "Sensors for Urban Operations".

Sensor requirements were derived from an IST-046 document on information requirements. These information needs were then categorized by mission area. Descriptions of applicable technologies were collected to evaluate against the information requirements. A workshop was held at the Defence College of Management and Technology (DCMT) in Shrivenham, UK in 2006 to evaluate various technologies. Both user/military and technology representatives were invited to the workshop to allow for the broadest interpretation of the utility of the sensors for solving a particular problem.

Through this study, the team determined that the single most important research area is multi-sensor integration: figure out how to make multiple, orthogonal sensors work together. No single sensor can solve the problem on its own. Using multiple modalities to gain deeper insight is necessary to better understanding the current situation. Furthermore, finding ways to make the sensors cooperate such that one sensor provides information to another sensor to increase its ability to make decisions is critical.

As multiple sensors are integrated to perform tasks together, size, weight and power will become even more critical than they are today. No military platform, whether that is a soldier, a vehicle, or an aircraft, can afford to add capabilities without reducing the size and complexity of existing sensors. Finding novel ways to power those systems, especially for soldier systems, is absolutely crucial.

Les capteurs pour les opérations en zone urbaine

(RTO-TR-SET-076)

Synthèse

Le groupe de travail SET-076 « Les capteurs pour les opérations en zone urbaine » a été formé en vue de déterminer les types de capteurs les plus utiles dans un contexte urbain et de recommander des domaines de recherche et des essais collaboratifs. L'équipe a entamé son étude à l'automne 2004. Le programme de travail a été modulé en fonction des travaux effectués par d'autres groupes : IST-046 « Les défis du commandement et du contrôle pour les opérations en zone urbaine », et le programme de coopération technique (TTCP) AG-09 « Les capteurs pour les opérations en zone urbaine ».

Les conditions requises en matière de capteurs ont été établies en se fondant sur un document de l'IST-046 relatif aux exigences d'information. Ces exigences d'information ont ensuite été catégorisées par domaine de mission. Les descriptions des technologies applicables ont été répertoriées en vue de les comparer aux besoins d'information. Un atelier s'est tenu en 2006 au *Defence College of Management and Technology (DCMT)* de Shrivenham, au Royaume-Uni, dans le but d'évaluer diverses technologies. Utilisateurs, militaires et représentants technologiques étaient conviés à cet atelier, afin de permettre l'interprétation la plus large possible de l'utilité des capteurs dans la résolution d'un problème particulier.

Grâce à cette étude, l'équipe a pu déterminer que le plus important domaine de recherche était indéniablement l'intégration multi-capteurs : comprendre comment faire fonctionner ensemble des capteurs orthogonaux multiples. Aucun capteur ne peut résoudre seul le problème. Le recours à des modalités multiples en vue d'approfondir les connaissances est indispensable à une meilleure compréhension de la situation actuelle. En outre, il est essentiel de découvrir comment faire coopérer les capteurs, de manière à ce qu'un capteur puisse fournir des informations à un autre capteur afin d'améliorer sa capacité à prendre des décisions.

Au fur et à mesure que des capteurs multiples seront intégrés pour accomplir des tâches ensemble, les considérations de taille, de poids et d'alimentation deviendront encore plus critiques qu'elles ne le sont aujourd'hui. Aucune plateforme militaire, qu'il s'agisse d'un soldat, d'un véhicule ou d'un aéronef, ne peut se permettre d'ajouter des capacités sans devoir réduire la taille et la complexité des capteurs existants. Il est absolument crucial de découvrir de nouveaux moyens d'alimenter ces systèmes en énergie, en particulier pour les systèmes destinés à équiper les soldats.

Chapter 1 – INTRODUCTION

1.1 PURPOSE

Increasingly NATO nations are being involved in military operations that are radically different from traditional scenarios, and that involve operations in towns and cities that may be occupied by a combination of non-combatants and hostile forces. This will lead to requirements for new concepts of operations to be developed, and the impact of novel sensors, or novel ways of deploying or using existing sensors to be investigated. Previous studies have looked at the requirements for operations in this new theatre but have not addressed sensor characteristics or limitations specifically.

SET-076 set out to investigate what sensors would be best utilized in an urban environment.

1.2 HISTORY OF THE GROUP

NATO SET-076/RTG-044 MSE "Sensors for Urban Operations" was formed in 2003 after an exploratory team showed the need for a group to examine what the requirements for sensors are in an urban environment. The initial charter was received in late 2002. Several of the key members of the group were unable to continue to their participation due to other commitments which caused the group to take a break to regroup. In early 2004, the group was reformed and began its work in September 2004 with a first meeting at RTA Headquarters in Paris, France.

Meetings were held semi-annually with the exception of 2006 when three meetings were held – mostly to prepare for and conduct the workshop.

Increasingly NATO nations are being involved in military operations that are radically different from traditional scenarios, and that involve operations in towns and cities that may be occupied by a combination of non-combatants and hostile forces. This will lead to requirements for new concepts of operations to be developed, and the impact of novel sensors, or novel ways of deploying or using existing sensors, needs to be investigated. Previous studies have looked at the requirements for operations in this new theatre but have not addressed sensor characteristics or limitations specifically.

1.2.1 Justification (Relevance for NATO)

Previous studies carried out within the RTO and elsewhere have indicated shortcomings in meeting information requirements when operating in an urban environment. Developments in sensor technology may offer some potential solutions to some of these, but it is unclear what fundamental limitations exist or where existing sensing methods could be used (perhaps in new combinations or with new ConOps) to meet these.

1.2.2 Objectives

A three year task group is proposed. The initial objectives of the group's activities are:

1) Define the sensing problems posed by operations in urban environments.
2) Identify likely shortcomings in current sensing capability, and predict likely sensor technology developments in the near future.
3) Define recommended research areas that will be needed to address the sensing requirements indicated by studies such as Land Operations 2020, Urban Operations 2020 (SAS-30), and various National studies.

4) Produce guidance on the fundamental limitations on sensor availability that are associated with urban/complex terrain.
5) Propose collaborative trials and/or assessment activities that will lead to a greater understanding of the true sensing capabilities, complementarities and limitations in urban operations.

1.3 PROGRAM OF WORK

The approved Program of Work outlined the following tasks:

1) Review previous studies including Land Operations 2020, Urban Operations 2020, to elicit the NATO military sensing information requirements specific to operations in urban environments. Create vignettes of possible urban operations scenarios.
2) Define the sensing problems posed by operations in urban environments.
3) Identify likely shortcomings in current sensing capability, and predict likely sensor technology developments in the near future.
4) Define recommended research areas that will be needed to address the sensing requirements indicated by studies such as Land Operations 2020, Urban Operations 2020 (SAS-30), and various National studies.
5) Produce guidance on the fundamental limitations on sensor availability that are associated with urban/complex terrain.
6) Propose collaborative trials and/or assessment activities that will lead to a greater understanding of the true sensing capabilities, complementarities and limitations in urban operations.

During the initial meeting the team agreed on an approach for achieving these results. Tasks 1 – 4 would lay the foundation for a workshop to be held in early 2006. The purpose of this workshop was to validate the vignettes and sensing problems posed, add sensing problems that the team missed, discuss technology shortfalls and create list of research requiring attention. All this would be accomplished with a broad team of technical experts and warfighter representatives from across NATO. From that workshop results would be compiled and included in the team's final report and recommendations to NATO SET.

Tasks 1-4 would be completed by April 2005 in order to begin preparation for the workshop. The Fall 2005 group meeting would focus on preparations for the workshop with the intent that the agenda, list of invited personnel, and open invitation would be published shortly thereafter. In January or February 2006 the team would conduct the workshop. After the workshop, the team would focus their energies on tasks 4-6, including summarizing the results from the workshop and writing the final report. With some hard work and perseverance, the final report would be turned in by December 2006.

1.4 BACKGROUND DOCUMENTATION

IST-046/RTG-018 conducted an urban war game in order to elicit information requirements for the urban battlespace. This exercise was focused on determining what information commanders in the field need in order to conduct a battle. Results from that exercised were documented in a report titled, "Results of IST-46 meeting 22-26 March 2004, The Hague" [1]. This report was the primary reference document for SET-076.

In this report, the IST-046 team documents several scenarios/vignettes used to determine what information field commanders would need to conduct operations in an urban environment. The main scenario is one of political unrest in a fictional country of Alliance of Caucasus States – specifically in the fictional border state of BATUMI. Possession of BATUMI has been disputed between ACS and its neighbour MAZURA for years. BATUMI has a mixed ethnic population. Several vignettes were designed to simulate peace keeping, peace enforcement, hostage rescue, riot control, and close-combat operations.

From these vignettes, listings of information requirements were developed. These information requirements were broken down into several groupings.

1) Static Physical;
2) Dynamic Physical;
3) Mental;
4) Enhanced Data; and
5) Command and Control.

These groupings were then further broken down by command level (Battalion and Company/Platoon) and planning time (Long Planning Time and Short Planning Time).

While IST-046 was focused on the information required to aid commanders in their task, SET-076 was focused on sensor requirements. There is a fine distinction between information and sensor requirements. For example, one information requirement enumerated by IST-046 was, "Request for a three-dimension map of the building (INFRASTRUCTURE: including stairs, windows, underground and all possible details and SERVICES: electricity, gas, water supply) – the viewing must be as realistic as possible and "change detection"-oriented. Moreover: air-conditioning network – for NLW (gas) use purpose" This is the information required – a 3D map of the area with lots of information on it. The sensor mission then is to collect that information. It could be stated this way, "Determine location of buildings, infrastructure, and routes including within buildings and below ground."

There are also information requirements which are nearly impossible to determine through a sensor – which completely unarmed civilians are potential combatants?

Reference was also made to RTO's "Land Operations in the Year 2020" [3] and "Urban Operations in the Year 2020" [2].

1.5 LIAISON WITH OTHER GROUPS

1.5.1 TTCP AG-09 "Sensors for Urban Operations"

Two members of SET-076 were also on the TTCP AG-09 team. Their program of work was nearly identical in scope and timing. This allowed for a great deal of interchange between the two teams.

1.5.2 IST-046/RTG-018 Command Center Challenges for Urban Operations

Members of the two groups SET-076/RTG-044 and IST-046/RTG-018 exchanged information and met for discussions for possible linkages and leverages. For example, the chairmen of SET-076 and IST-046 met and an IST-046 member presented an overview of IST-046 during the SET-076 meeting in Canada in September 2005. In addition, a SET-076 member participated in the IST-046 meeting held in Canada in October 2005 and briefed IST members on work in-progress.

Chapter 2 – METHODOLOGY

2.1 SET-076 STUDY METHODOLOGY – SETTING UP FOR THE WORKSHOP

Methodology for tackling problem: The team then got down to the details of how to tackle the problem presented in the program documents (TAP/TOR/POW). Much discussion was conducted on gaining an understanding of the problems presented by the urban environment. Should that include user requirements or simply a physics-based approach of fundamental limitations? Clearly there are many different urban environments and many different scenarios. For example: peacekeeping vs. full-scale military operations. The UK Urban Operations study has a developed procedure that was examined for its utility in solving our specific problem. The methodology identified is as follows:

a) ID Mission Scenarios/Vignettes.

b) Go through capabilities with each mission profile to ID likely sensor problems.

c) Take to user to get their input on our thinking.

d) Identify shortcomings of existing sensors.

e) Discuss and identify technology being developed to address d).

f) Recommend list of technology to address technologies and phenomenologies not in e. and not in currently in use with a focus on what could be fielded in the next 5-10 years.

The team devised the following strategy (which was documented in the POW):

a) Review previous studies including Land Operations 2020, Urban Operations 2020, to elicit the NATO military sensing information requirements specific to operations in urban environments. Create vignettes of possible urban operations scenarios.

b) Define the sensing problems posed by operations in urban environments.

c) Identify likely shortcomings in current sensing capability, and predict likely sensor technology developments in the near future.

d) Define recommended research areas that will be needed to address the sensing requirements indicated by studies such as Land Operations 2020, Urban Operations 2020 (SAS-30), and various National studies.

e) Produce guidance on the fundamental limitations on sensor availability that are associated with urban/complex terrain.

f) Propose collaborative trials and/or assessment activities that will lead to a greater understanding of the true sensing capabilities, complementarities and limitations in urban operations.

2.1.1 Defining the Sensing Problem

IST-046 had done significant work to define the types of information that are required by commanders in an urban engagement [1]. This work was leveraged to identify the sensing problem. A set of questions were devised to guide the discussion of the urban sensing problem.

- What can be sensed to solve this requirement?
- What main sensor(-s) could be used?
- What supporting sensors could be used?
- Physical limitations of those sensor mode/technology.

- Limitation of existing sensors system.
- Working method with data.
- Carrier (Use of the sensor) as currently envisioned.
- Threat against sensor/carrier.

We started out by going through each sensing requirement and answering the questions. The team quickly came to the realization that going through each item was not necessary. Many of the items had the same type of sensing problem. So we decided to group the items into similar sensing requirements. The following categories were chosen:

- Mapping facilities;
- Mapping route;
- Mapping utilities;
- ID;
- Tracking;
- Detection;
- Classification; and
- Other Study (not an item that would be covered by a sensor; such as "The ability to contact the local police and how long it will take the police to arrive at the checkpoint.").

These were further combined and formal definitions created to make the requirement clearer. As we discussed the definition of each of these areas we learned that we all had a different idea of what they meant. The team thus devised a set of formal definitions to ensure that workshop participants would be able to discuss the technologies without dispute as to the definition of the requirement. The final set of requirements and their definitions were:

- Mapping: Determining location and state of buildings, roads, utilities, routes (non-moveable objects – things that don't move on their own) and geo-locating them (placing them in an absolute coordinate system).
- Identification: The determination of the origin, nature, and characteristics of a detected person, object, or phenomenon. This may be accomplished by various means including visual recognition, electronic interrogation, flight plan correlation, and the interpretation of acoustic information, behaviour, and/or hostile action.
- Tracking: Knowing the current location of moving objects (forces, individuals, vehicles, missiles, aircraft, etc.) within some uncertainty factor.
- Detection: The discovery by any means of the presence of a person, object, or phenomenon of potential military significance.
- Classification: To arrange or order as belonging to a particular group (e.g. man or vehicle, wheeled vs. tracked).

2.1.2 Technologies for Evaluation

The next step in the process was to select a set of technologies to evaluate. These were solicited from participating countries. A comprehensive list of possible technologies was produced to use as a guide to collecting the technology descriptions. An attempt was made to get as broad a set as possible. We originally focused on getting technology sheets that described specific technologies but soon settled on accepting technology sheets that focused on specific programs.

Two worksheets from other studies were used as templates; one from the NATO RTO Urban Operations 2020 study and one from a study conducted by the US Joint Urban Operations Office. To keep things simple, a single-page format was used. Fields were consolidated and eliminated as needed.

All the sheets provided were divided among the requirement areas by the team (see Annex A – for the complete list and groupings). This was to serve as a guide for workshop participants in the breakout sessions. This list would act as a starting point for evaluating how well a requirement was met. Teams could also take technology sheets from other groups and evaluate them against their requirement if they thought the technology had some merit in that area.

2.2 SET-090 WORKSHOP

2.2.1 Purpose of the Workshop

Early in the process of developing this study, the members of SET-076 realized that more voices were needed to arrive at some consensus conclusions about the utility of various sensors in an urban environment. For this reason the team decided to hold a workshop to bring together experts from throughout NATO, Sweden and Australia. At this workshop experts in the various technologies along with military experts would discuss the utility of each technology against a set of requirements. From their comments and ratings some discussion of the ability of each technology, and all technologies in aggregate, to meet the urban sensing requirements would be arrived at.

While not scientific, this process would highlight the strengths of the technologies and point out any gaps in capability. Furthermore, the discussions were designed to allow free interchange between technologists and military users. Such a discussion would serve to edify the participants – technologies on how their systems would be employed and users on new and developing technologies.

2.2.2 Workshop Organization

The workshop was divided into two main parts. During the first part (the first two days of the workshop) papers were presented on both scientific and military topics. The purpose of these papers was to orient the military members to the technologies and the technologists to the urban sensing problem. During the second part of the workshop (the final two days) members were broken into several groups. These groups were given a specific sensing requirement to evaluate technologies against.

2.2.3 Workshop Methodology

Technology description sheets were allocated to the various sensing requirements. Those sensing requirements were further refined to identify which level of command was being investigated. The final set of requirements were:

- Platoon – Detect, Track and ID;
- Battalion and Air Platforms – Detect and Track;
- Battalion and Air Platforms – Detect, Classify and Identify; and
- Mapping.

Workshop participants were broken down into these four groups. Each syndicate was given the task to “Evaluate technologies for how much of the urban sensing requirement under discussion will be solved by each technology presented”. During the breakout sessions, the following structure was used to collect comments and votes on each technology description:

1) Take 2 minutes to read a technology description sheet.
2) Someone in the group who is knowledgeable of the technology under consideration will give a quick overview.
3) Group members will ask questions and discuss the technology to gain a better understanding of how it might be used to solve the sensing requirement under evaluation.
4) Each member will vote on how much of the sensing requirement this technology solves.
5) Collect comments for why the technology solves the requirement and why the technology does not solve the requirement.
6) Repeat with all technology description sheets applicable to this requirement.

Comment sheets were distributed so that participants could record their thoughts and votes on paper. This was so that more elaborate comments could be made and collected by the chairman. The voting was mostly there to get people to consider the system in a broader context.

Key to the process was the collection of comments. It is in those comments where the real results were found. Each of the syndicates found that time management was a major issue. Most people were excited by the topics being considered so a lot of discussion took place on how each of the technologies could be used. Participants were encouraged to write down their thoughts during those discussions so that syndicate chairmen could later go back and collect all the comments.

2.3 POST-WORKSHOP ANALYSIS

To get the lessons-learned down, syndicate chairmen used the comment sheets, scoring workbook, and technology description sheets to summarize the conclusions reached during their breakout session. Syndicate reports started with analysis of each technology description sheets including pros and cons and a summary of the comments. Finally, conclusions about the requirement area were drawn.

2.4 GENERAL COMMENTS ON THE PROCESS

It is obvious that it is a challenge to gather a large group of participants from various nations and knowledge/working background looking into this specific and complex problem. However, the breakout sessions were quite smooth with many interesting discussions and debates. Useful points were made and noted. Ideas were presented, evaluated, clarified and re-evaluated. Many positive as well as negative comments were made and noted, upon the agreement with the group, toward each technology. In addition, the presence of military users was proven vital to the breakout session as they were able to quickly and precisely link the questioned sensing technology to the vignettes. There was certainly, as expected, bias on some technologies regarding which are considered more important. Nevertheless, most participants were open-minded for new ideas and enthusiastically asked questions if in doubt. Also, bias might play a role on some low and high scores. However, the fact that each group consisted of experts from various fields permitted a safe assumption and from observation that the scoring/voting would level out any significant favouritisms toward a particular technology.

Many of the technology description sheets were general and not detailed enough for in depth evaluations. Also the application of the technology was not specific and the evaluators had to guess and make assumptions. The vignettes were helpful to focus and bounding the needs and problems. Some participants had to leave early but provided their comment sheets (many thanks to them for their professionalism). However, these comments were provided without a group discussion. In general, the group agreed on the differences as well as the agreeable. Both positive and negative comments were captured for your own consideration on how the technology best fit in your needs and investments.

2.5 KEY TO RATING SYSTEM

In the following sections results of the breakout sessions will be presented. In those results, a rating system is used to define how well we can currently do the job and to help focus attention on areas for future work. There are three mission areas: Pre-combat (Pre), Major Combat Operations (MCO), and Post-combat (Post).

Pre-combat (Pre) is defined as the period before hostilities begin. This period is characterized by little or no access to the areas to be attacked, no time to prepare on the ground at the attack site, and only those sensors available which you are able to bring with you or commandeer when you arrive. It is, however, also characterized by some knowledge of force structure and location of enemy fixed targets and forces.

Major Combat Operations (MCO) is defined as a period of force-on-force. This is envisioned as a full assault of uniformed or well organized militias operating in a traditional head-on manner (not terrorist actions). During major combat operations some site preparation is possible. For example, sensors can be left at a scene to allow a unit to be alerted to the presence of enemy in an area already cleared.

Post-combat is inclusive of peace keeping, peace enforcement, stability operations, counter-insurgency, military operations other than war (MOOTW), etc. This period includes hostilities against non-traditional urban adversaries. Generally, forces will have access to all areas for sensor site preparation – the London camera system being a good example.

Chapter 3 – BATTALION/AIR PLATFORMS AND PLATOON – DETECT AND TRACK

by

Dr. Philips Laou
Dr. Morgan Brishoual

3.1 INTRODUCTION

In urban operation forces need to conduct operations against conventional or unconventional enemy forces in all types of terrain and climate conditions and all spectrums of conflict (major theatre war, smaller-scale contingency, and peacetime military engagement). During continuous operations, leaders and soldiers must think faster, make decisions more rapidly, and act more quickly than the enemy.

To do this, forces employ a multi-level, integrated suite of intelligence, reconnaissance, and surveillance assets with assistance of several kinds of sensors. The entire information collected by the sensors provide the force commanders with a unique capability to visualize, describe, and direct the brigade through the full spectrum of operations and terrain in which the unit may be operating in urban operation.

In this session we focused our thoughts on sensing technologies which could be useful for detect and track moving objects in battalion/air platform level (Mission plan and command) as well as platoon level (Operation).

3.2 DEFINITION: BATTALION/PLATOON/AIR PLATFORM – DETECT AND TRACK

(The following definitions are extracted from a SET-076 working document **Battalion/Air Platforms/ Platoon – Detect and Track**)

- **Detect:** The discovery by any means of the presence of a person, object, or phenomenon of potential military significance.
- **Track:** Knowing the current location of moving objects (forces, individuals, vehicles, missiles, aircraft, etc.) within some uncertainty factor.

3.3 SENSING TECHNOLOGIES

Sensing technologies were pre-selected as potentially "the technology" to address the above sensing problems. The detailed Technology Description Sheets are available in Annex A. These technologies could be categorized as acoustic sensing, optical sensing, and radar sensing. The sensing Technology Description Sheets evaluated during this session were: 2, 7, 8, 10, 11, 12, 14, 15, 17, 18, 19, 20, 21, 22, 35, 37, 38, 42.

3.4 ASSESSMENT OF CURRENT SENSOR TECHNOLOGY

The table below shows the color-coding assessment of the technology. In each of the blocks an explanation is given for why the technology was rated this way. In the last column a recommendation on technologies that could be used to solve the problems sited is given.

3.4.1 Battalion – Detect and Track

	Pre	MCO	Post	Technologies recommended
In the open	Radar/EO/acoustic sensors enough sophistication providing enough resolution; Obscured targets under trees, combatants in a crowd of people; Further improvement possible with sensor/data fusion	Elevated activities hard to sufficiently separate the blue/red/white, generally too much activity detection to be useful; clutter and moving objects; Improvement possible includes info from soldier sensors networked to battalion level	As progress past MCO, still difficult to determine red from white; clarity in detection needed to separate interesting detection/tracks from uninteresting ones. In some cases, tracking may need to be done for an extended period to get info out of current sensor; red force will try to hide from detection; Improvement possible includes fusion with similar or dissimilar sensors	Data/sensor fusion, soldier network including wireless, sensor network including multi/hyperspectral imaging, wave (radar and acoustic) propagation in urban environment
Buildings	No mature technology to detect and track target inside building from stand-off	Less time than in the open with limited technologies available; Improvement possible includes info from soldier sensors networked to battalion level	More time to setup a radar network, acoustic or EO system; gain some improvement when we have access to the buildings to place sensors	TTW sensing at large stand-off distance, data/sensor fusion, soldier sensor network including wireless, consolidated existing technologies (e.g. wider field of view (FOV)), wave (radar and acoustic) propagation in urban environment
Underground	No technology sufficiently mature for underground detect and track target from stand-off at battalion level	No technology sufficiently mature for underground detect and track during conflict at battalion level; Improvement	Robot with EO and radar sensors could be sent underground; gain some improvement when we have access to the	Stand-off ground penetrating radar (GPR) with fast processing, data/sensor fusion, soldier sensor network including wireless, wave (radar

	Pre	MCO	Post	Technologies recommended
Underground (*continued*)		possible includes info from soldier sensors networked to battalion level	undergrounds to place sensors and info from soldier sensors networked to battalion level	and acoustic) propagation in urban environment

3.4.2 Platoon/Soldier – Detect and Track

	Pre	MCO	Post	Technologies recommended
In the open	n.a.	Many EO soldier systems fielded covering visible, I2, IR.	Many EO soldier systems fielded covering visible, I2, IR; red force will adapt to blue force action and try to avoid detection	
Buildings	n.a.	Current EO soldier systems are not designed for close proximity action providing reduced performance; Other systems such as radar systems (TTW imager from Time Domain), scope cameras, Spybowl, and a robot with EO sensors could be used. However, there are deployment challenges during conflict; Radar technology (TTW) needs more investigations for robust surveillance inside buildings and for quick installation; high performance systems are still too complex for deployment; data ambiguity of radar systems still exists due to wall materials and multilayers, etc.	More time to setup a radar network, acoustic or EO system; other systems such as radar systems (TTW imager from time domain), scope cameras, Spybowl, robot with EO sensors could be used; Radar technology (TTW) needs more investigations for robust surveillance inside buildings and for quick installation; high performance systems are still too complex for deployment; data ambiguity of radar systems still exists due to wall materials and multilayers, etc.	Consolidate existing technologies (e.g. wider FOV), data/sensor fusion, soldier sensor network including wireless, TTW technologies, wave (radar and acoustic) propagation in urban environment

	Pre	MCO	Post	Technologies recommended
Undergrounds	n.a.	Current EO soldier systems not designed for close proximity action in undergrounds providing limited performance; robot operation is still a challenge underground e.g. drop zones in sewage systems	Current EO soldier systems not designed for close proximity action in undergrounds providing limited performance; robot operation is still a challenge underground e.g. drop zones in sewage systems	Consolidate existing technologies (e.g. wider FOV), data/sensor fusion, soldier sensor network including wireless, man portable GPR, wave (radar and acoustic) propagation in urban environment

The following are general challenges in current sensor technology for detect and track:

- Limited line-of-sight of the environment.
- EO systems designed for medium-to-long range in the open provide too high magnification and too narrow coverage in close proximity action – too narrow FOV.
- Logistically challenging to deploy sensors with limited time and information on the area of operation.
- Sophisticated sensors have size, weight, and power consumption issues.
- Timeliness of information with sensors providing large amounts of information.
- Many current sensors are not networked.
- Need more sensors in an urban environment due to geometry issues and clutter.
- Complex wave propagation is a challenge to acoustic and radar systems in urban environment.
- Shadows and light reflection off objects are a challenge to EO systems in an urban environment.
- Need better knowledge of wall materials and structures (multilayers, etc.) for TTW imagery.

3.5 SUMMARY COMMENTS

In the above sensing technologies, one could categorize them into:

1) Radar;
2) Acoustic;
3) Optics; and
4) Joint sensing technologies.

Some of them were designed for urban operations, and others were technologies originally used in conventional warfare but now also being used in urban operations.

Radar technology and particularly through-the-wall sensing are considered very important in urban operations, however, the supreme open-field, very long range, highly accurate (both spatial and temporal) radar technology still faces some uphill challenges when it is to be re-engineered for urban operations. This was reflected from the low scoring on some radar sensing technologies within our group in which two radar experts voted these technologies low as well with others. Many of the radar technologies evaluated here have some capabilities for through-the-wall situational awareness from simple target detection to counting and tracking. However, they are often linked with limits such as weight, size, power consumption, multiple units with stationary deployment, and unknown detection properties against various wall materials. Some of these technologies were specifically designed for urban operations and are relatively new to the military – there is less experience and military heritage associated with them. Since this is the only standoff, through-the-wall situational awareness technology, more efforts and resources are needed to advance the technology.

Compared to radar technology, acoustic and optical sensing technologies find a smoother way to address urban operation requirements although some fundamental challenges will never go away. For example, the physical complexity and materials used in the environment have significant impact on detection accuracy using acoustic sensors. In the case of electro-optical sensors, the limited line-of-sight (LOS) in an urban setting severely hampers any surveillance operations. The mid- to long-range EO systems having a narrow FOV are not effective in an urban setting where LOS averages between 50 and 100m and often shorter. However, some current systems designed for conventional battlefields find their way into urban operations with lowered but acceptable performance such as acoustic arrays for small arms detection and other EO surveillance systems. Since these existing technologies have military heritage, it is relatively less challenging to adopt them. Some uniquely designed systems have been successful to provide more situational awareness such as the SPYBOWL.

One comment raised is the weak linkage between some of these sensing technologies and command and control. The sensing technologies will benefit more if the collected information can be sent to, understood and used by commanders at the strategic, operational and tactical levels. In some cases, the capabilities of the sensing technologies can be increased by many-fold with a proper command and control plan. Another comment is on the choice of sensing technologies: cost vs. performance. Low cost sensors can be mass deployed for large area coverage and redundancy while expensive sensor systems provide more accurate and detailed data. The first one is preferred in surveillance missions while the latter one is preferred if the mission involves delivering weapon effects.

The use of the designated four vignettes facilitated discussion on potential sensing/information requirements. However, there are some threats that are not covered under these vignettes leading to the reduced appreciation of the corresponding detecting technologies. For example, chemical or biological threats are not unrealistic but are not present in the vignettes. Although these attacks are unlikely, they are possible. One recent example is the case where the cult Supreme Truth released the nerve gas sarin during a Tokyo morning rush hour in 1995. More discussion needs to take place on how to address this threat with consideration on limited R&D resource and odds of occurrence.

3.6 COMMENTS ON EACH TECHNOLOGY

(The comments are based on the details on each Technology Description Sheet provided by technologists and scientists).

3.6.1 Technology Description 2 – Acoustic Sensor Network (3.7 on 5)

Clarification on Technology

This sensor concerns an acoustic technology dedicated for surveillance of an area. It can detect, classify and track temporary sound sources of vehicles, group of people or gunfire. This sensor could be use in an acoustic network.

Positive Points for the Technology

It is a stationary solution for area monitoring. It is a relatively cheap technology with networking capability. It could be used as queuing sensors (complementary or secondary) via network. A pre-deployed system could be used to prepare the area for battalion. Military user acknowledged that this technology is useful for Vignette 4 to detect ambush and other activities, and could be useful for Vignette 2 as well providing that one has time to deploy it. It could be used to track the group and monitor whether the riot spreads.

Negative Points against the Technology

It is not for mobile platforms and this limits the tracking capability and only for localized, predefined areas. The direction of movement is satisfactory but precision on position and accuracy for gunshot detection/direction are less satisfactory. Military user expressed that the technology is less useful in Vignette 1 since pre-deployment may not be possible.

General Impression on the Technology

This technology is useful in urban operations but the capability could be extended with reasonable and achievable efforts.

3.6.2 Technology Description 7 – Portable Low Cost Radar for Imaging and Communication (2 on 5)

Clarification on Technology

The concept of this technology is to use a number of low cost radar sensors for both radar imaging and mapping (LOS, NLOS or through-the-wall) and communication within a network for surveillance.

Positive Points for the Technology

This concept has potential positive impact on security system and radar network for communication. It could be part of a low cost sensor suite complimenting, e.g. acoustic or motion sensors for personnel detection. This technology may also be used in commercial radar applications.

Negative Points against the Technology

The only negative point against the proposed technology is that this system is needed to be deployed in advances. On the concept itself, however, there are some unresolved methodologies on how to realise this concept, e.g. what frequency for see-through-the-wall, imaging, and communication; what are possible antenna(s) requirements for multiple frequencies.

General Impression on the Technology

This technology is useful in urban operations but the technology and performance need more clarification and development.

3.6.3 Technology Description 8 – Hyperspectral VNIR/LWIR: Scopes/Binocular, Surveillance, Sniper Detection (3.9 on 5)

Clarification on Technology

By integrating a custom visible-near-IR CCD and a long wave IR microbolometer detector array, hyperspectral visible images are captured by the CCD while hyperspectral long wave IR images are captured by the bolometer array. More target features (colors, symbols or letters on targets, facial features, etc.) could be acquired during daylight while target detection and recognition are possible in complete darkness. Hyperspectral imaging is potentially useful to detect difficult targets. The technology was designed for portable systems.

Positive Points for the Technology

Assuming Visible, Near IR and LWIR imaging capabilities are all in the same package, it provides enhanced capability. It is useful for sniper detection. It is an additional capability in urban operations with limited usefulness in Vignettes 1, 2 and 3.

Negative Points against the Technology

This technology is useless in NLOS situation, e.g. cannot provide situational awareness by see-through-the-wall or see around corners or over buildings, and cannot provide situational awareness if objects are covered and concealed completely. It requires LOS to a target which is usually limited in urban environments. The existing LOS range is also relatively short, e.g. 50-100m on the street and less than 10m inside a building. A small FOV may not be feasible and useful. It is not an autonomous system with automated/aided targeting capability.

General Impression on the Technology

This technology has some usefulness in urban operations providing additional target imaging information. The translation from the designed technological capabilities to situational awareness is hampered mainly by the lack of LOS in an urban environment.

3.6.4 Technology Description 10 – Miniradar – Handheld Doppler Radar for Through-the-Wall-Sensing (3.3 on 5)

Clarification on Technology

This technology allows a through-the-wall-sensing by detecting movement of objects behind a wall. The handheld sensor is held against the wall during acquisition and it is possible to detect moving objects 5 to 10m behind a 20cm thick concrete wall.

Positive Points for the Technology

It is a good technology with unit at low cost and light weight to detect movement of objects behind a wall. It could be useful for Vignette 4 using as an orthogonal sensor in a sensor suite for activity sensing.

Negative Points against the Technology

This technology cannot be used to track moving objects and is not capable of determine number of objects. Other sensors are needed. There is also detection sensitivity problem associated with multilayer walls. In addition, the fact that the system must be against the wall during acquisition, this posts potential threat to personnel. It will be better if one can operate and monitor it at a standoff distance for safety.

General Impression on the Technology

Through-the-wall situational awareness is considered a main capability gap in urban environments. This technology provides a first through-the-wall situational awareness by detecting moving objects behind a wall with low false alarm. In many cases, this may be all the information needed. By associating with other sensors, object tracking and counting may be possible.

3.6.5 Technology Description 11 – Long Wavelength Infrared (LWIR) (4.4 on 5)

Clarification on Technology

The presented technology is passive uncooled thermal imagery. Thermal energy corresponding to 8 to 12 µm infrared emitted by an object is detected by a detector array. An image is then constructed according to the detected signal. Image requisition is possible in total darkness and under fog and common battlefield obscurants. However, it could not see through glass.

Positive Points for the Technology

This is a mature technology with wide range of applications from soldier surveillance sight/weapon sight, helmet mounted system, to mobile platforms such as vehicle and UAV. The operational range could be up to 2 km depending on optics. This technology is also relatively low cost and could be queued by other sensor/system for collaborated sensing. Systems using this technology are usually compact and light weight that makes it ideal as soldier systems. This technology could be useful in Vignettes 1, 2, 3 and 4.

Negative Points against the Technology

The main disadvantage of this technology is that it could not image through glass or window. The resolution (MOTS state-of-the-art at 640 by 480) is also low compared to that of visible (14M pixels), and cooled MWIR (>1k by 1k resolution) and some LWIR imaging technologies. It is not compatible to standard NIR aiming devices and this contributes problems of target localization and designation missions.

General Impression on the Technology

It is a proven MOTS technology. It provides valuable battlefield information within its limitation.

3.6.6 Technology Description 12 – Coherent Radar Through Wall System (3.7 on 5)

Clarification on Technology

The dielectric properties of different wall materials allow electromagnetic waves at microwave frequencies to propagate through walls. Coherent mono-pulse radar techniques facilitate the detection of very weak radar signals from a moving target behind walls. Radar images could be acquired from incoherent measurements. The maximum object distance from wall is estimated to about 30m depending on wall materials and layers. It must be static during operation.

Positive Points for the Technology

It is a good concept to detect people in motion through walls. It can detect, track, and count multiple people. It can associate with several radar units at the same time to increase accuracy. The radar could be deployed some distance from the walls making it safer for the operators. It could be useful in Vignette 3 to detect potential hostile activities inside a room. It is also very useful in hostage situations.

Negative Points against the Technology

The weight and the complexity of deployment are the major drawbacks. The system must be in a highly static environment during operation. Several systems are needed to cover a large area. It needs more studies on real performance against range of wall materials.

General Impression on the Technology

Through-the-wall situational awareness is considered a main capability gap in urban environments. On the other hand, huge efforts are needed to develop more compact systems with robust deployment due to the nature of urban operations.

3.6.7 Technology Description 14 – Sensor System for Vehicle Situation Awareness (4.4 on 5)

Clarification on Technology

A matrix of cameras (visible and/or thermal) is used to provide wide area coverage outside an armoured vehicle. The operators inside the vehicle receive a seamless image of any direction with optional augmented information like threat detection within field of view.

Positive Points for the Technology

It provides good situational awareness with wide field of view (360°) and improves the safety of personnel with less body exposure outside the vehicle. It is good for peacekeeping missions and could be useful in Vignettes 1 to 4.

Negative Points against the Technology

There are concerns on possible blind spots and camera failure. Camera redundancy might be required in the system design. Human factors are important as any latency in real time could cause sickness. A stereovision might be better adapted by users.

General Impression on the Technology

It provides enhanced situational awareness and personnel safety using mature technologies. More work is needed to address human factor issues.

3.6.8 Technology Description 15 – Tunable THz Imager (4.1 on 5)

Clarification on Technology

A passive THz imager that is tunable from millimetre wavelengths to thermal wavelengths according to field environment. The resolution is better in thermal imaging mode, however, lower resolution, shorter range millimetre wavelength mode provides images in dusty conditions. It is a TRL 1-2 technology.

Positive Points for the Technology

It is a good concept and could be useful in Vignettes 2, 3 and 4.

Negative Points against the Technology

Since this is a TRL 1-2 technology and there are limited details available on the technology, it is impossible to make criticisms.

General Impression on the Technology

The concept will provide new sensing technology and this technology is definitely useful in urban operations.

3.6.9 Technology Description 17 – Caladiom: Unattended Ground Alert Sensor (2 on 5)

Clarification on Technology

When a potential moving target is detected at a maximum standoff distance of 1000m this sensor wakes up other high performance sensor (IR Camera, radar, acoustic, etc.) for further investigation as identification. This unattended ground alert sensor uses Programmable Artificial Retina (PAR) technology to survey and analyze an area. It is a TRL 6 technology which does not include, for the moment, infrared PAR technology.

Positive Points for the Technology

In urban operation, this sensor could survey an area continually for several days or weeks. It is a good system to protect close area such as a camp or a building.

Negative Points against the Technology

This sensor alone is not beneficial. It needs to be combined to other sensors. The system is useless with smoke and obscurant presence and the preliminary version of this sensor is based on a visible PAR which does not allow night time surveillance. The extended range of detection may not be useful in a dense urban environment where LOS is limited. A low cost passive IR motion sensor will provide the same capability.

General Impression on the Technology

The alert concept is interesting to protect close area. However, the fact that it has to combine to another sensor is a limitation in urban environment. The long detection range may also not be applicable in urban operations. More work is needed to address night survey. As a result, it has limited usefulness in urban operations.

3.6.10 Technology Description 18 – DAOTE: Acoustic-Optronics Device to Detect Hidden Sniper (3.7 on 5)

Clarification on Technology

DAOTE is a combination of one optronic and three acoustic systems all managed by a remote display to detect hidden sniper. The optronic part consists of a daytime camera with multiple field of views, a pointed optical system, a laser range finder and a laser pointer to designate the detected target.

Positive Points for the Technology

The technology is quite mature (TRL 7) with two combined sensing systems (optronics and acoustics) allowing a better threat detection. It is a good system to provide situational awareness in an urban area and give a good solution for extension of the area of monitoring. The system will detect gunner sight before sniper firing and detect ammunition trajectory after sniper firing. It could be useful in Vignette 3 for building protection in a statically environment and in Vignette 4 for surveillance. It is also useful for Vignettes 1 and 2 if placed on a mobile platform. User expressed willingness to bring it anywhere with a vehicle.

Negative Points against the Technology

The field of view is probably limited for the optronic part. This system does not allow wireless link to the platoon to send image/localization of the target. It is easily detectable by the enemy and could be dangerous for the operator to operate near the sensors.

General Impression on the Technology

It is a good concept to provide situational awareness in an urban area and to detect hidden sniper but this concept is probably limited in urban operations as it is configured.

3.6.11 Technology Description 19 – PILAR: Acoustic, Sniper Detection (3.1 on 5)

Clarification on Technology

PILAR is system using mature acoustic technology (TRL 9) which is similar to the more sophisticated sensor DAOTE. It is an acoustic sensor to detect hidden sniper position by processing the wave propagation of the muzzle blast and the shock wave created by the bullet when travelling at supersonic speed.

Positive Points for the Technology

The sensor makes acceptable detection at up to 50m between sensor and bullet passage point and can operate in noisy environment and be mounted on a vehicle. It is a good system to provide situational awareness in an urban area, to platform and buildings. It could be useful in Vignette 3 for building protection in a statically environment and in Vignette 4 for surveillance. It is also useful in Vignettes 1 and 2 if placed on a mobile platform. User expressed willingness to bring it anywhere with a vehicle.

Negative Points against the Technology

The detection range is limited. This system is dedicated to specific applications and is limited to two directional acoustic sensors connected to a remote display. It does not allow wireless link to the platoon to send image/localization of the target. It is easily detectable by the enemy and could be dangerous for the operator to operate near the sensors.

General Impression on the Technology

This concept is probably limited in urban operation as configured.

3.6.12 Technology Description 20 – CLEO: Through Wall Imaging Sensor (1.9 on 5)

Clarification on Technology

This sensor is an L-band FM CW radar which allows a through-the-wall-imaging by detecting movement of objects behind a wall. The sensor consists of three radars held against a wall during acquisition. It is possible to detect moving objects from 2 to 12m behind a 20cm thick concrete wall. By triangulation tracking processing, a very good accuracy could be obtained.

Positive Points for the Technology

The sensor can detect and track moving target behind a wall with low false alarm. The sensor is useful for special operations and an excellent localization and tracking distance are obtained by triangulation of the three radars. The sensor can be combined to an acoustic sensor.

Negative Points against the Technology

The sensor could only be used in limited operation since it needs to be mounted against the wall. The three radars need time to be deployed. It does not allow wireless link to display control.

General Impression on the Technology

This technology provides through-the-wall situational awareness by detecting and track moving objects behind a wall with low false alarm. More efforts are needed to improve operational robustness (reduction on weight, numbers of pieces, size, etc.) for urban operations.

3.6.13 Technology Description 21 – COBRA: Counter Battery Radar (4.1 on 5)

Clarification on Technology

COBRA is C-band active array radar which performs high accuracy location of hostile battery positions and predicts impact points within very short transmission periods. 40 batteries can be detected at up to 40km range and detection is reported to a command control in less than two minutes.

Positive Points for the Technology

The concept is mature (TRL 8) and the system is useful at the beginning of an event to detect mortar attacks. The radar could cover a large area (until 40km by 90 degrees in azimuth). The accuracy on mortar locations and impact points is very good (depending on the mortar but less than 75m at 40km). It could be useful in Vignette 3 for force suppression and likely in Vignette 4 for maintaining urban surveillance at a brigade level. The radar can be placed at a distance from a town.

Negative Points against the Technology

The radar is limited for 81mm batteries detection and this technology is expensive. The radar will need to be coupled to another sensor (e.g. acoustic system) to address unconventional weapon in urban operation and to alert where the mortar will fall. The system does not cover 360° detection.

General Impression on the Technology

The radar could be used as an intelligence tracking of hostile batteries on a city. Since it is not possible to perform counter measure against a dense urban environment by CORBA and it provides less situational awareness in “shoot-and-run” tactics, a second “eye-in-the-sky” system coupled to COBRA could be used to obtain better reconnaissance and even perform a more precise counter measure.

3.6.14 Technology Description 22 – CUIRACE: Foliage Penetration (1 on 5)

Clarification on Technology

This sensor is an UHF pulse Doppler waveforms radar which can detect and track vehicle (up to 6km range) or helicopter (10km) hidden behind a mask or foliage.

Positive Points for the Technology

The radar covers 360° in azimuth by electronic switching.

Negative Points against the Technology

The radar is not mature to detect hidden objects behind buildings.

General Impression on the Technology

The radar is useful in conventional battlefields, however, its usefulness is limited in urban operations.

3.6.15 Technology Description 37 – Short-Range BioSpectra (1.9 on 5)

Clarification on Technology

Based on laser-induced fluorescent spectrometric detection, this compact LIDAR system can monitor large indoor and semi-enclosed outdoor spaces for biological threats in aerosol form. The system is eye safe and can form a network with more or other type of sensors.

Positive Points for the Technology

It provides a warning signal upon biological agent detection. The system could perform classification using a library of fluorescing spectra. It was suggested that it could also be used as personal scanning system.

Negative Points against the Technology

The system could not track the threats and false alarms might still be an issue without a fairly completed database. There are general concerns over UV exposure causing cancers. The public perception on this technology may be difficult to alter in favour of system deployment. It is not a platoon level system (too specific) and not applicable to all vignettes.

General Impression on the Technology

Its applications are limited in urban operations as biological attacks are rare in the near future rendering lower priority.

3.6.16 Technology Description 38 – SPYBOWL FELIN's Optronic Ball (4.6 on 5)

Clarification on Technology

Spybowl is a handheld "optronic ball" which can be rolled or thrown like a grenade and designated to be as simple and as ruggedized as possible. It provides instantaneously to the soldier (infantry troops or Special Forces) a 360 degree view of the area. Spybowl integrates four miniaturized cameras (enabling a full omnidirectional view), a microphone, a battery (autonomy of 1 hour) and a radio link for data transmission (standoff distance at 30m inside a building and 100m in open field).

Positive Points for the Technology

It can be used in potentially dangerous confined areas such as building and caves. The four cameras allow a 360 degree view. It could be useful in Vignettes 2 and 3.

Negative Points against the Technology

The unit is not equipped with IR or IL sensors yet. The cost could be critical for lot of them. Each camera need to be clearly referenced. The deployment scheme of throwing an object could be considered as a hostile act.

General Impression on the Technology

It is a good concept for urban operations and its design is specifically to enhance situational awareness in urban settings from rooftops, rooms, to tunnels and sewers (need IR) at low cost with lightweight.

3.6.17 Technology Description 42 – Active Defence Sensor System (2.1 on 5)

Clarification on Technology

This technology concerns coherent microwave radar combined with a passive IR system. The radar has multiple receivers to achieve the necessary tracking accuracy and coverage. The radar is dedicated to vehicle protection against projectiles and missiles in urban areas. The radar range is estimated to be around 100-200 m.

Positive Points for the Technology

The concept is mature (TRL 5-8) and seems interesting for detect and track. Information from the radar can be used to queue other sensors and personnel. The system is mobile and mounted on an armoured vehicle.

Negative Points against the Technology

The detection range seems too short for a reaction and false alarm can be a problem. In case of subsequent action required it may cause collateral damage issues. The concept is restricted to self protection. The current configuration is too heavy to be used in urban operations such as against riots.

General Impression on the Technology

It will be useful in an urban operation to queue others upon detection.

Chapter 4 – PLATOON – DETECT, CLASSIFY AND IDENTIFY

by

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4.1 INTRODUCTION

In urban operations the soldier on the ground will be a system by himself but also a part in systems-of-systems together in his squad and platoon. The platoon consists normally of three or four squads and an equal number of vehicles. The soldiers are both mounted and dismounted, as well as indoors and outdoors, in bright daylight and in complete darkness. Sometimes the vehicles are used in other situations and not available to support the dismounted soldier.

To do this the soldier-systems must be easily carried by the soldier with some supporting systems mounted on the platoon-vehicles. The situations for the platoon can be divided in two perspectives either in beforehand with sensors being placed in the area of action before action or carried by the platoon and used as they are moving.

In this session we focused our thought on sensors which could be useful from detection to identifying objects.

4.2 DEFINITION: PLATOON – DETECT, CLASSIFY AND IDENTIFY

- **Detect Definition:** The discovery by any means of presence of a person, object, or phenomenon of potential military significance.
- **Classify Definition:** To arrange or order as belonging to a particular group (e.g. man or vehicle, wheeled vs. tracked).
- **Identify Definition:** The determination of the origin, nature, and characteristics of a detected person, object, or phenomenon. This may be accomplished by various means including visual recognition, electronic interrogation, flight plan correlation, and the interpretation of acoustic information, behaviour, and/or hostile action.

4.3 SENSING REQUIREMENTS: PLATOON – DETECT, CLASSIFY AND IDENTIFY

In order to evaluate each technology according to their effectiveness in an urban operation, the following typical sensing/information requirements generated from studies of simulated urban operation vignettes (extracted from a "Results of IST-46 meeting 22-26 March 2004, The Hague"[1]) were considered on each technology:

4. Obtain status of vehicle destruction Time of completion Presence and state of wounded, friend or foe and state of destroyed vehicles.

1. Require information about the enemy forces. Require information about the nature, volume and location of the enemy forces. Location: in our AOR but also well outside our AOR. Require continuous surveillance on specific areas. Require information on exact and real-time location of the enemy leader (for determining intent or also for targeting). Require information about enemy fire locations (e.g. sniper detection). 1. Require BDA on past fights.
Where are the students (specifically the ones with weapons) on the campus; in what buildings and rooms.
Recent situation on the roofs of the buildings on the campus (Vignette 2) and Provincial Legislative Building (Vignette 3) as well as the buildings in the near surroundings.
4. How many weapons and type of weapons are inside the campus (Vignette 2)?
8. Where are the ZFL and the BFF leaders? Are they in the vicinity and can they be contacted? (Vignette 2).
Are they carrying weapons?
10. Information on the people (red and white) in the houses? (Vignette 3) Location and equipment of individual enemies (specifically where is their leader?). Number of enemy in the four houses (three north of the main building). Where is the main enemy focus (in which house are most of the enemy)? Are there non-combatants in the house? Are the opposing forces wearing explosives on their bodies? People being held hostage? Request for SF. 11. For the blue forces outside of the building, blue force tracking of the people inside the building is needed. (for possible fire support from outside)
12. Need reception of updated picture.
BLUE position and state.
RED position, state, intent, etc.
Also info about YELLOW (unknown).
15. Update status of own troops – company – as required. 19. Status of injuries and the scope of damages. Request remote triage.
21. Need to see through the walls for enemy positions.

22. Information about the enemy forces. 23. Require time sensitive targeting (targets of opportunity, moving targets). 24. A foe" discrimination system – individual soldier – inside building. 25. To know if there is civilian (and where) inside the building.

Classification Requirements

Require continuous surveillance on specific areas. Require information on exact and real-time location of the enemy leader (for determining intent or also for targeting). Require information about enemy fire locations (e.g. sniper detection). 27. Obstacles like manholes, mines, explosives etc. Static and dynamical obstacles.
28. Information of moving objects (possible threats) behind the surrounding buildings.
Look at something unusual like people carrying weapons, crowds etc. How do the population react on the scene?

Detection Requirements

11. Obstacles like manholes, mines explosives etc. The assumption is that the platoon commander has received instructions how to react on obstacles (recce or alternative route).
12. Possible threats from the buildings. From inside the building. From the top of the roofs. Underground complexes.
13. 360 degree coverage from the vehicles.
Where are the students (specifically the ones with weapons) on the campus; in what buildings and rooms. Recent situation on the roofs of the buildings on the campus as well as the buildings in the near surroundings of the campus.
Are they carrying weapons?
10. Information on the people (red and white) in the houses? (Vignette 3)
Location and equipment of individual enemies (specifically where is their leader?). Number of enemy in the four houses (three north of the main building). Where is the main enemy focus (in which house are most of the enemy)? Are there non-combatants in the houses?
21. Need to see through the walls for enemy positions. 22. Information about the enemy forces.
23. Require time sensitive targeting (targets of opportunity, moving targets).

24. Dynamic alert (change detection including human-motion detection.
25. To know if there is civilian (and where) inside the building.
27. Obstacles like manholes, mines, explosives, etc. Static and dynamical obstacles.
28. Information of moving objects (possible threats) behind the surrounding buildings. (extending the view of the commander to react more rapidly) Area of interest. Look at something unusual like people carrying weapons, crowds, etc.
How do the population react on the scene?
29. Information if there are people using the sewer system or not. 30. 360 degree coverage from the vehicles.

4.4 SENSING TECHNOLOGIES

Sensing technologies were pre-selected as potentially "the technology" to address the above sensing problems. The detailed Technology Description Sheets are available in Annex A. These technologies could be categorized as acoustic sensing, passive and active optical sensing and radar sensing. The sensing Technology Description Sheets evaluated during this session were: 3, 4, 5, 6, 7, 8, 9, 11, 14, 15, 17, 18, 19, 23, 24, 26, 28, 29, 30, 31, 32, 33, 34, 37, 38, 41 and 43.

4.5 ASSESSMENT OF CURRENT SENSOR TECHNOLOGY

The table below shows the color-coding assessment of the technology. In each of the blocks an explanation is given for why the technology was rated this way. In the last column a recommendation on technologies that could be used to solve the problems sited is given.

	MCO	Post-Combat
In the Open Requirements: 1) ID targets at distances longer than the opponents weapon efficiency. 2) ID of red (from green), quick responses at short distances	Preparations are done. You are supported by the battalion sensors and you can concentrate on detecting with your platoon sensors. **Technology Recommendations:** 1) Hyperspectral and laser to detect difficult targets at mid- and long ranges. In case of obscurants (smoke, dust etc.) a radar sensor can support the optical system.	You have to rely on the platoon sensors to detect and identify. The mix of combatants and civilians is a problem. **Technology Recommendations:** 1) Hyperspectral and laser to detect difficult targets at mid- and long ranges. In case of obscurants (smoke, dust etc.) a radar sensor can support the optical system.

	MCO	Post-Combat
3) ID of IED as well as suicide bombers	2) In daylight a visual system is sufficient. In low light conditions and with obscurants you need multi-spectral systems combined with a radar. 3) Hyperspectral imager and high resolution radar (mm-wave and THz). Radiometry systems might be interesting alternative to the radar (reflecting the microwave from sky or sun).	2) In daylight a visual system is sufficient. In low light conditions and with obscurants you need multi-spectral systems combined with a radar. The time limitation is a key issue. 3) Hyperspectral imager and high resolution radar (mm-wave and THz). Radiometry systems might be interesting alternative to the radar (reflecting the microwave from sky or sun).
Buildings Requirements: 1) ID of red (from green), quick responses at short distances 2) ID of IED	The possible preparations are done and you have detected some kind of threat level that you have to identify with the platoon system. **Technology Recommendations:** 1) Preparation of the building before entrance in order to detect possible threats with radar (and possibly also laser and acoustic sensors). 2) Blue-force tracking preparation (i.e. RFID). 3) Hyperspectral to detect difficult targets at short ranges. 4) Hyperspectral imager and chemical sensors (not discussed during the WS).	Very little preparation is done and you have to relay on the platoon sensors with the short reaction time for ID and final decision making. **Technology Recommendations:** 1) Preparation of the building before entrance in order to detect possible threats with radar (Difficulty to use multiple sensor systems, like laser and acoustic due to time limitation). 2) Blue-force tracking preparation (i.e. RFID). 3) Hyperspectral to detect difficult targets at short ranges. 4) Hyperspectral imager and chemical sensors (not discussed during the WS).
Underground Requirements: 1) ID of red (from green), quick responses at short distances 2) ID of IED	A little preparation to estimate the threat level can be done, but then you have to rely on the platoon sensors with the short reaction time for ID and final decision making. (Difficult environment) **Technology Recommendations:** 1) Preparation of the underground systems during advance with radar (Doppler) and acoustic sensors.	Hard to make preparations even to estimate the threat level. You have to rely on the platoon sensors with the short reaction time for ID and final decision making. (Difficult environment) **Technology Recommendations:** 1) Preparation of the underground systems during or in advance with radar (Doppler) and acoustic sensors.

	MCO	Post-Combat
	2) Blue-force tracking preparation (i.e. acoustics/RFID?). 3) Hyperspectral to detect difficult targets at short ranges (UGV or soldier). 4) Hyperspectral imager and chemical sensors (not discussed during the WS).	2) Blue-force tracking preparation (i.e. acoustics/RFID?). 3) Hyperspectral to detect difficult targets at short ranges (UGV or soldier). 4) Hyperspectral imager and chemical sensors (not discussed during the WS).

4.6 SUMMARY COMMENTS

The main conclusion from the session is that no sensor can solve everything.

The military needs technologies that have low-cost, low-weight and low power consumption. The sensor system should be used by an operator with very little training!

How can we get the soldier enough time (or distance) to identify the threat – we have to find solutions to that.

We have quite a few sensor solutions for the soldier to detect things but we have problems identifying a hostile individual before he becomes a hostile. The main problem is identification. Who is a threat in a crowd? How can we get the soldier enough time (or distance) to identify the threat? We have no solutions to that at present. One of the biggest problems today is the separation of combatants from non-combatants. IED detection is a general problem. For IED nothing good exists. The sensor range has to be similar to the weapon ranges. Within this range the soldier should be able define whether a person is a friend or a foe. The degradation of optical technology systems are not obviously so severe at these short distances → all weather capability.

Interesting technologies for further research and development are:

Radar has a great advantage compared to other sensing systems by having ability to see through adverse weather. Radar will often only give detection and tracking capability. To reach the identification level more integrated systems have to be developed. The use of higher frequencies is preferable to gain higher resolution imaging. One interesting system concept is to combine data from radar sensors working in different wavelength bands. The challenge is the signal processing part to handle very large amount of data and extract something useful of it. Can such systems be used to identify threats, for example armed people? Reliable TTW systems for stand-off detection are preferable in many applications.

Hyper-spectral imaging sensors operating in visual, NIR, SWIR, MWIR and LWIR bands are very interesting – both cooled and un-cooled. The cooled systems are less noisy but need lots of power and in the platoon perspective means vehicle-mounted systems. The un-cooled systems need less power which implies smaller systems that can be handheld or be put on an UAV. The challenge is to find the optimal soldier systems: helmet mounted or weapon mounted, which can be operated in bright light as well as in complete darkness. The system should help the soldier with real-time threat *identification* at different ranges.

The laser technology systems enable 3-D capacity, see through partially concealed objects (i.e. Venetian blinds, curtains and vegetation) and vibrometry.

Acoustical systems can primarily be used together with other types of sensors for identification.

No sensor can solve everything, the solutions has to be find in combination of technologies such as:

- Hyperspectral and mm-wave to detect and identify threats in a crowd.
- Radar, laser and acoustics to detect and hopefully identify threats in a building.
- Hyperspectral and laser to detect difficult targets at mid- and long ranges.
- Hyperspectral soldier mounted systems for the urban environment combined with some kind of RF ID for blue force tracking in buildings and underground.

4.7 COMMENTS ON EACH TECHNOLOGY

(The comments are based on the details on each Technology Description Sheet provided by technologists and scientists).

4.7.1 Technology Description 3 – Combined mm/Optical Surveillance System

Score Range: 1-3; Average Score: 2.2

Clarification on Technology

(50-100 kg, TRL 2).

Positive Points for the Technology

Useful for camp surroundings or other fixed site location. Good if possible to install the sensor in advance. The system will point out were things happens and this is a useful thing. Good for localizing and providing ID.

Negative Points against the Technology

Primarily it's a line of sight system. Limitation based on atmospheric limitations, for example in smoke and fog. The system has limited tactical applicability to operations at platoon and may be easily obscured. The system is too expensive, too heavy and too large in size to be handled by a dismounted soldier. Even a mounted system will perhaps be too heavy. The system would give lots of false alarms in an urban area.1 km range may not be feasible, there are better frequencies that offer high performance and low cost.

General Impression on the Technology

There are other technologies that exceed this system – other things which might do the same job which will work better.

Military user expressed the techno is less useful for vignette 1.

4.7.2 Technology Description 4 – Hyperspectral Imager in Visual/Near IR

Score Range: 3-4; Average Score: 3.5

Clarification on Technology

Hyperspectral imager in visual/near-infrared (1 kg, but needs high power and data fusion, TRL system 5).

Positive Points for the Technology

Automatic target recognition based on identification of spectra in different wavelengths. During the daylight the only UAV based sensor is in the visual spectra. This system will give new capability to detect and detect different objects. Image fusion is very nice. The sensor is useful for material classification. Provides increase over present day/NIR. Good vehicle- mounted system. It has good capabilities on a UAV due too the light weight. System does address daylight operating gap. Very useful for ATDRT (Automatic Target Detection, Recognition and Tracking).

Exploits image fusion concept. High TRL level and low cost.

Negative Points against the Technology

The operator has to identify the objects due to its shape. It requires good transmission in daylight and not useful in bad weather. Low update rate and platform dependent. Requires high power and bandwidth, may limit utility. Highly relates to what is visible by eye.

General Impression on the Technology

Should perhaps be combined with other sensors. Overlay this visual imagery for detection improvement. Enable switching between this and visible imagery. Reduce power requirement. Power will make this succeed or fail. Small UAVs carry minimal power additional to the sensor payload. Transmission of data required, possible image processing challenges or post processing? The range capability needs to be clarified.

Military user expressed the use on smaller UAV in vignette 1, 2, 3 and 4.

4.7.3 Technology Description 5 – Free Space Optical Communication

Score Range: 2-4; Average Score: 3.7

Clarification on Technology

Wavelength 1.55 micrometer. Point-to-point communication with the LOS system.

The transmitter for the Non LOS is directed against the sky. High bandwidth. Weather dependent which limits for long range applications. Jamming resistant. (LOS 3 kg, TRL 9, Non LOS 50 kg, High power, TRL 5).

Positive Points for the Technology

Point-to-point communication. High bandwidth → much info can be transmitted. It enables long range transmission, 50-100 km. Possible useful on platoon level.

Resistant against jamming.

Negative Points against the Technology

Reliable transmission is weather dependent. LOS concerns about the CONOPS you have to identify the receiving point – perhaps this is a problem. LOS system needs power.

General Impression on the Technology

Today we (US Army) are jamming ourselves in the urban environment. Today often FM, UHF is used with to low bandwidth. This is an enabling technology. Perhaps this technology should belong to the battalion category due to its high data rate and long range communication. If this is an alternative to regular communications, it will be an excellent enabler to operations, employed at Battalion level to enable communication at all echelons.

UV system is the important one not LOS system.

Military user expressed the techno useful as supporting (enabling) technology to the platoon.

4.7.4 Technology Description 6 – Optical Sight Detector

Score Range: 2-4; Average Score: 3.2

Clarification on Technology

Detect and localize retro-reflected optical radiation from optical sights. The time-response can be used to characterize the sight. (5-10 kg, TRL 9).

Positive Points for the Technology

Fast scanning, 360 degrees. The system can be used to detect snipers if they are using optical sights. The instant detection of snipers is a very important feature.

Negative Points against the Technology

You need to change the frequency relative the sight. Weather restrictions are not so severe in this case. This type of system, even smaller, already exists. Snipers in Iraq don't often have optical sights. So the system will not give so much. Not all optic devices will be detected.

Power and weight binds dismounted operations. There is a risk that an opponent with a goggle or an illuminator will be dazzled or blind. Non-eye safe laser will blind anyone behind an I^2, unitary or magnified optic. If pursued, Geneva Convention rule must be addressed.

General Impression on the Technology

The false-alarm rate in urban environment is unknown. Potentially you could retrieve reflection from a human eye – but the signal level will be too weak. If need, the system will primarily be on vehicle and at Company/Platoon level.

Military user expressed the techno is useful for vignette 1, 2, 3 and 4.

4.7.5 Technology Description 7 – Portable Low Cost Radar Sensor for Imaging and Communication

Score Range: 2-5; Average Score: 3.2

Clarification on Technology

Portable low cost radar sensor for imaging and communication (0.5 kg, TRL 3).

Positive Points for the Technology

Include all buzzwords that are demanded in a recent US Study. If it can perform everything that it says. The system has low weight, radar and communication capability. Fog and smoke penetration capability. Blue force detection and tracking in a building. If possible, very useful for pre-mapping of buildings!

Negative Points against the Technology

The multipath effects are severe inside building. This technology will not give anything more than other techniques for detecting and identification. Triangulation for location needs more then 3 sensors. Short range and area surveillance imply network of sensors. Must use GPS to accomplish tasks.

General Impression on the Technology

The interesting focus in the discussion concerned the ability inside buildings. Technical performance may not be possible in practice. There was an expressed scepticism if the system will perform well in this environment. But it might and because of that it must pursue!! Contradiction; wall penetration needs longer wave-lengths but short wave length for imaging.

(See Roke's UWB technologies, NUAIR research programme on UWB and Netted Sensor research programmes.)

Military user expressed the techno is useful for vignette 2 and 3.

4.7.6 Technology Description 8 – Hyperspectral VNIR/SWIR/LWIR

Score Range: 2-4; Average Score: 3.6

Clarification on Technology

Hyperspectral VNIR/SWIR/LWIR (portable, TRL 6-7).

Positive Points for the Technology

The robustness of the system. Good urban performance. It can be used in so many applications. The system is small, has light weight with multiple uses. ATR (Automatic Target Recognition)-capability. By changing optics different range bands can be achieved. Possible use for IED-detection. It's also useful for integration with other sight devices. Processor has great potential, multi band in long and short IR is better than less bands.

Useful in most weather and light conditions and VNIR will allow you to see through glass.

Negative Points against the Technology

The system is more suitable for open terrain – it has very little to give in the urban terrain.

General Impression on the Technology

Today's IR-sights don't perform so well in daylight. You can camouflage as good in urban terrain as in normal terrain. It must have the same or better resolution of 25 micron FPA.

Military user expressed the techno is useful for vignettes 1 and 4, protect and checking around a camp.

4.7.7 Technology Description 9 – Multi/Hyperspectral Thermal Imager

Score Range: 1-2; Average Score: 1.8

Clarification on Technology

Multi/hyperspectral thermal imager (5-150 kg, needs high power and bandwidth, TRL 5).

Positive Points for the Technology

The system can be able to cover urban terrain. Not limited for daylight operations. The system can also see through common battlefield obscurants. MWIR and LWIR HS-capability is still very interesting for UAV-reconnaissance and surveillance at platoon level.

Negative Points against the Technology

Old technology similar task can be done by # 8, smaller, cheaper, non-scanning. It's really not a platoon system. Data must be transmitted or processing on-board? High power (1000 W) restricts for dismounted use and perhaps for platoon use. The 150 kg version is too heavy and big for Platoon use and in UAVs.

General Impression on the Technology

This is today's technology.

Military user expressed the techno is useful for vignette 4.

4.7.8 Technology Description 11 – Long Wavelength Infrared (LWI)

Score Range: 2-4; Average Score: 3.0

Clarification on Technology

Long wavelength infrared (LWI) (Weapon sight, TRL 9).

Positive Points for the Technology

This technology is useful in low or non-light situations. It gives the operator hot-spot detection. The LWI penetrates smoke and can work in poor weather conditions to some degree. Has the advantage of using uncooled passive technology. The technology is useful in MOUT and for UAV/UGV applications.

Negative Points against the Technology

You don't get range. The resolution is too low. Better systems exist today. In tropical conditions MWIR will be better due to high water vapour.

General Impression on the Technology

Current technology, this is off-the shelf technology It should have 640x640 pixels. Increase range and FOV (Field of view).

Military user expressed the techno is most useful for vignette 2 and 3.

4.7.9 Technology Description 14 – Sensor System for Vehicle-Situation Awareness

Score Range: 3-5; Average Score: 3.7

Clarification on Technology

A sensor system for vehicle-situation awareness which is integrated in a vehicle.

The system tracks the operator's head movement and provides an image as if the user were looking in that direction. Lack of system information. (Vehicle integrated system, TRL 5).

Positive Points for the Technology

It could be a situation awareness system for the soldiers in the truck before they operate, especially needed for urban environment. Our current vehicles are developed for open terrain otherwise they should have this kind of system. You go from today's zero capacity – this is needed. This would be an excellent technology to have.

Negative Points against the Technology

The field of view in the neighbourhood of the vehicle must be solved.

General Impression on the Technology

The commander needs 90 degree of sight.

UK MoD is already funding a similar programme.

There is a program similar to this one in the US called TASK. It is a scanning system trying to solve the problem of vehicle protection. There were problems because it is a scanning system.

(See Roke's vision technologies.)

Military user expressed the techno is useful preferably in vignette 1 and 4. But all vignettes can contain vehicles.

4.7.10 Technology Description 15 – Tuneable THz Imager

Score Range: 1-4; Average Score: 2.9

Clarification on Technology

Tuneable THz imager. Uses high resolution images is IR when possible and switches to mm-wavelengths when needed to maintain image capability in dusty conditions. (Vehicle mounted, TRL 2).

Positive Points for the Technology

Could penetrate dust. It gives high resolution which is an advantage. Vision during bad conditions (dust, cloud, smoke) is a large benefit. The system can be used to see through clothes. It is useful for long range detection. System for dusty situations, such as firing in urban terrain – how often is there a problem with obscurants?

Negative Points against the Technology

Large antenna sizes are needed to collect high resolution. Vehicle mounted only.

General Impression on the Technology

Much more research has to be done. Potential to provide capability, however, without any type range indicated, frequency, needs detectors? – the system cannot fully be evaluated.

(See Roke's 150 GHz, MMW and UWB Imaging technologies, including HWS CWIDS, PTHZ, ATHZ, PANDORA ™.)

Military user expressed the techno is useful for vignette 3 and 4.

4.7.11 Technology Description 17 – Unattended Ground Alert Sensor (CALADIOM)

Score Range: 1-3; Average Score: 2.0

Clarification on Technology

Unattended ground alert sensor that uses a programmable artificial retina – 200x200 pixels focal plane array. The technology is incorporated in a system that could be used in urban operations (1.6 kg, TRL 6).

Positive Points for the Technology

It is as an unattended low power long waiting sensor to wake up and cue a higher power higher sensitive/resolution sensor.

Negative Points against the Technology

The resolution is to low. It has limitations in FOV for wake up use.

General Impression on the Technology

It is not unique. There are many other sensors that can be used as a wake up sensor. No improvement compared with today's system.

(See Roke's SINNER technology.)

Military user expressed the techno is useful for vignette 2.

4.7.12 Technology Description 18 – Acoustic-Optronics Device to Detect Snipers (DAOTE)

Score Range: 3-4; Average Score: 3.3

Clarification on Technology

This acoustic-optronic device to detect snipers consists of a combination of sensors:1 day camera, laser rangefinder, 1 laser pointer, 3 acoustic antennas and a display module (no weight specified, TRL7).

Positive Points for the Technology

Extra capability compared to system 19 – adds imaging capability for looking at the location where the gunfire came from.

Negative Points against the Technology

System is not mobile. Limited use for Platoon size element.

General Impression on the Technology

System of system. Not so much difference between Technical sheets no 18 and 19. No mention of reliability. Would probably use this for an important base as to detect snipers etc.

(See Roke's HALO technology.)

Military user expressed the techno is useful for vignette 1 and 2.

4.7.13 Technology Description 19 – Acoustic, Sniper Detection (PILAR MKII.w)

Score Range: 2-4; Average Score: 3.0

Clarification on Technology

Acoustic, sniper detection system that consists of 2 acoustic sensor arrays and a display (no weight specification, TRL 9).

Positive Points for the Technology

Performed very well in recent field test. The system can perform well if the operator is trained specially in open terrain.

Negative Points against the Technology

Problem with wind. The problem is the dismounted case. Problems if the system is standing close to walls. It's limited primarily to fixed-site protection. The technology has high FAR (False Alarm Rate) in urban environments due to echoes.

General Impression on the Technology

Fielded two years ago. Then it performed on vehicles functionality only at checkpoints. Additional work has been performed since then. In urban terrain the position is important for its performance. Work is done to reduce the false alarms. More useful for current combat situation because snipping consists more of run up fire and run away, than optical site snipping.

(See Roke's RF system research for bullet detection and Roke's HALO + IR technology.)

Military user expressed that this technology is most useful for vignette 1, 2 and 3.

4.7.14 Technology Description 23 – DEMISTER

Score Range: 1-4; Average Score: 2.5

Clarification on Technology

System for detection and localization of laid and buried mines. (>100 kg, TRL 6).

Positive Points for the Technology

This approach is much simpler to use compared with smaller mine detecting systems. Good for clearing an area or a route.

Negative Points against the Technology

The velocity forward during the mine detection is slow, but . If the mines can be detonated manually and remotely the system might be useless. Demister is not considered as a platoon asset and it is doubtful whether it is useful in MOUT.

General Impression on the Technology

Detection in real time but the classification is carried out in post-processing. There is no indication of cleaning speed and therefore the area coverage rate is not known. Discussion of remote mines and asphalt mines. Not really a platoon system.

(See Roke's SPLICE and RF sensor technology and research programmes.

See Roke's mine detection research programmes.)

This technology is most applicable to vignette 4 in which you are already in trouble. If you have to clear the area around the camp it might be useful.

4.7.15 Technology Description 24 – Active Imaging System

Score Range: 1-3; Average Score: 2.3

Clarification on Technology

Active Imaging system with a combination of a thermal imager, laser-diode illuminator and a gated intensified CCD camera. Depending of application the system is capable of either detecting optical sights, gather information and monitor activities many km away or identify a man at many hundreds m (20 kg, TRL 9 – commercially available).

Positive Points for the Technology

The active part of the system can penetrate windows and glass. A great advantage is that you can perform range gating. You can tune it to the range gate where the target you want to image is supposed to be, and then perform classification and identification. By using a larger antenna you can achieve very high angle resolution. The range gating capacity is good. The system is very good for long range but not so common in urbane environment.

Negative Points against the Technology

It doesn't add more capability for urban operations. The system is too expensive. Limitations include LOS operation.

General Impression on the Technology

More likely to be used in mounted operations, which may be on platoon level. Much of the technology already exists.

This technology is applicable to vignette 1.

4.7.16 Technology Description 26 – Near Infrared System (NIR)

Score Range: 2-3; Average Score: 2.4

Clarification on Technology

NIR camera features an increased sensitivity in the near-IR range which peaks at 760 nm. (<1 kg, TRL 9).

Positive Points for the Technology

Low-light capability. Higher resolution than a standard intensity amplifier is an advantage. Small size and low weight < 1 kg. Fusion possibility in the future. It helps identifying people.

High TRL and relatively low cost are positive. Light enhancement performance may be an advantage.

Negative Points against the Technology

It can not be used inside buildings and tunnels (without artificial or ambient light).

These cameras don't give more resolution than NVG (GenIII) and are bigger and heavier (for 64x480). Not completely dark proof.

General Impression on the Technology

Could be put on a helmet. It seems to be a camera-like application. Same frequencies as the SWIR – doesn't match properly with Tech. description 32. Uncertainty about the main advantage with this sensor.

This technology is applicable to vignette 2 and 3.

4.7.17 Technology Description 28 – EO Imagery

Score Range: 3-4; Average Score: 3.3

Clarification on Technology

EO imagery in the visual region. (< 1 kg, TRL 9).

Positive Points for the Technology

This technique is very useful in the urban environment. It is also very inexpensive, small and mature. Useful for ground troops, UAV and AV. The sensing output is like the human sensing which makes its easy to interpret.

Negative Points against the Technology

Weather dependent technology. Only daylight performance.

General Impression on the Technology

This is not a system this is a concept. The described resolution is not the state of the art.

This technology is applicable to vignette 1, 2 and 3.

4.7.18 Technology Description 29 – Image Sensor Fusion for Soldier-Borne Applications

Score Range: 3-5; Average Score: 3.7

Clarification on Technology

A typical fused system consists of a VIS/NIR sensor for high resolution imagery and a LWIR sensor for long range target detection. (Weight not specified, TRL 4-7).

Positive Points for the Technology

Combine the best of two worlds: Long-range detection in the long-wave region. Identification is carried out at the shorter wavelength band. Give benefits in the urban environment. The fusion of two techniques is interesting.

Negative Points against the Technology

The size and weight and perhaps power requirement is limiting for the use of the system.

General Impression on the Technology

Image fusion system (handheld). Combination of LWIR and VIS/NIR. The long range detection needs a cooled bolometer. LWIR is for hot spot detection. Two optics will give parallax errors. Similar helmet mounted systems has already been tested in US (uses 2AA batteries, can be operated for a couple of hours). Presentation with monocular vision goggle.

This technology is applicable to all vignettes.

4.7.19 Technology Description 30 – Mid-Wavelength Infrared Sensors (MWIR)

Score Range: 2-4; Average Score: 2.7

Clarification on Technology

The MWIR band offers nearly 100% transmissions, with the added benefit of lower, ambient, background noise. (2 kg, TRL 5).

Positive Points for the Technology

Good range performance. Can perform well in complete darkness. The long range performance makes it suitable for reconnaissance and surveillance applications → the system will preferable be placed at a high level structure (house etc.) looking down on the scene. The system is totally passive and the size and weight and power requirements are moderate. No target illumination needed which gives good urban performance. Operates in darkness and background clutter. Non-cryo. Has advantages compared to NIR.

Negative Points against the Technology

Weights about 2 kg → too heavy to be helmet mounted or be put in a gunsight. Perhaps handheld system. It can't penetrate dust and smoke.

General Impression on the Technology

MIDIR (totally thermal). Could be cooled by a thermoelectric cooler. The MID-wave IR will perform better than LWIR in maritime applications with very constant backgrounds and high vapour. LWIR works better in urban environment, where the contrast between target and background is better. [MID-wave is totally thermal].

Very high thermal sensitivity gives good long range detection but this is not often needed in urban environments.

This technology is applicable to vignette 1 and 2.

4.7.20 Technology Description 31 – Compact Atmospheric Sounding Interferometer (CATSI)

Score Range: -; Average Score: -

It's not applicable for the platoon.

Clarification on Technology

Passive stand-off LWIR chemical vapor sensor. Area surveillance for chemical threat up to 5 km. (<50 kg, TRL 6).

Positive Points for the Technology

Item not scored because it is not applicable to the Platoon.

Negative Points against the Technology

Item not scored because it is not applicable to the Platoon.

General Impression on the Technology

The member of the session did not vote on this technology.

4.7.21 Technology Description 32 – Short Wave Infrared (SWIR) Sensors

Score Range: 2-4; Average Score: 3.3

Clarification on Technology

SWIR detectors and cameras. (<0.070 kg, TRL 9).

Positive Points for the Technology

SWIR detectors can see objects with better resolution than thermal cameras and they can also see through glass. Very small, light and cheap. High resolution and good for stand-off monitoring.

Negative Points against the Technology

The range of this technology is limited to 50 m. The FPA temperature limitations might be limiting. SWIR detectors are passive (only uses reflected light) and will not work inside indoors.

General Impression on the Technology

Night Vision Lab has a 1-2 km range system – mounted on a tripod (system size 30x30x30 cm) [SWIR is thermal in the 600 degree Celsius region so under normal conditions its only depending on reflecting light → no functionality inside houses]. Compared to system (29) it has increased sensitivity over NVG. But it will need a display.

This technology is applicable to vignette 2 and 3.

4.7.22 Technology Description 33 – Active Millimeterwave Sensor

Score Range: 2-4; Average Score: 2.9

Clarification on Technology

Short range high resolution in 3D. Use installed on a vehicle. Four sensors installed on vehicle corner to scan 360 degrees. (no weight specified, no TRL specified).

Positive Points for the Technology

Can detect opponents in the urban environment during bad sight conditions.

Useful for advancing platoon.

Negative Points against the Technology

The limited resolution limits the sensor's utility.

General Impression on the Technology

This technology is applicable to vignette 2, 4.

4.7.23 Technology Description 34 – Passive Real-Time Millimeter-Wave Imager

Score Range: 3; Average Score: 3.0

Clarification on Technology

Passive detection and imaging of the mm-wave radiation that is emitted naturally from the body. The blockage of the signal by any metal or plastic material will produce an image. Resolution 32x64 pixel and a frame rate of 5 images. (No weight specification, no TRL specification).

Positive Points for the Technology

Compared with nothing this system is an aid for a platoon. This is more of a peace-keeping system.

Negative Points against the Technology

Physically large. People have to be kept close to scanner. More suited to peace keeping than conflict.

General Impression on the Technology

To use this system the platoon has to put up a checkpoint to use the sensor. It is a possible system.

(See Roke's HWS CWIDS technology and Roke's PMMW and AMMW technology).

This technology is applicable to vignette 1 and 4.

4.7.24 Technology Description 37 – Short-Range BioSpectra

Score Range: -; Average Score: -

This is not really a platoon system.

Clarification on Technology

Compact LIDAR system based on spectrometric detection of laser-induced fluorescence to monitor large indoor and semi-enclosed outdoor spaces for biological threats in aerosol form. (<20 kg, TRL 3).

Positive Points for the Technology

This is a fairly small LIDAR system, which gives time to put on protection equipment.

Negative Points against the Technology

Could perhaps be used by a platoon if it could be mounted on a vehicle.

General Impression on the Technology

The member of the session didn't vote on this technology.

4.7.25 Technology Description 38 – SPYBOWL FELIN's Optronic Ball

Score Range: 3-4; Average Score: 3.9

Clarification on Technology

Spybowl integrates 4 miniaturized cameras, a microphone and a HF radio for data transmission in a range up to 30 m inside buildings and 100 m in open areas. (<5 kg?, TRL 6).

Positive Points for the Technology

This technology can be rather useful in many aspects in the urban warfare. Could for example be thrown inside buildings or at cross-roads. This concept is simple, delicate and cheap.

Can give the soldiers a picture of the situation in an enclosed area before you enter.

Negative Points against the Technology

Limited range. Limited battery life. The small video cameras only permit for operations in daylight or in artificial light.

General Impression on the Technology

There were discussions around the TRL level. May this system already exist?

(See Roke's SPINNER and NUAIR technology).

This technology is mainly applicable to vignette 3. But it can also be useful in vignette 2 and 4.

4.7.26 Technology Description 41 – Combined mm/Optical Stand-Off Check Point System

Score Range: 3-4; Average Score: 3.9

Clarification on Technology

The system consists of a mm-wave radar/radiometer operating at 220 GHz combined with a passive optical system. To be able to identify a person the optical system will be operated in a high resolution mode guided by the radar/radiometer. It will facilitate detection of weapons concealed under clothing (25-50 kg, TRL 2).

Positive Points for the Technology

The system has good stand-off capability. It is perfect for screening purposes at checkpoint.

The system will help you to detect people who are potential threats at bases and checkpoints.

Negative Points against the Technology

A problem is that you don't see the back of the person. Possibly high FAR.

General Impression on the Technology

For checkpoints or secured areas.

(See Roke's HWS CWIDS technology and Roke's PANDORA technology and variants).

This technology is applicable to vignette 1, 2 and 4.

4.7.27 Technology Description 43 – 3-D Ladar for UAV (UGV)

Score Range: 3-4; Average Score: 3.3

Clarification on Technology

A 3-D laser radar mounted on a UAV or UGV enables high resolution 3-D images. ID of targets or surveillance of a limited area. (20 kg, staring system TRL 5, scanning system TRL 9).

Positive Points for the Technology

Day and night capacity and it will also work in rain. The system can give the soldiers some extra information that can be very useful. Good for UAV applications.

Negative Points against the Technology

It's not so obvious when to use this technology. Fog and haze will degenerate the system. The system is perhaps a little bit too heavy for the platoon level.

General Impression on the Technology

It could be mounted on a ground vehicle, a tripod, on a roof or an UGV to get a 3D view of the street. Can also be used to see through a fence or vegetation and camouflage net, with the multiple hit capability. In this description a scanning system is described, and the staring system development is mature. A small system has a range up to 1 km.

(A lightweight system with 128x128 pixels has been demonstrated (Flash – staring sensor, 6 kg, Advanced Scientific Concepts Inc. ~1 km capability.)

(See Roke's Hystar MD system.)

This technology is applicable to vignette 3 and 4.

Chapter 5 – BATTALION AND AIR PLATFORMS – DETECT, CLASSIFY AND IDENTIFY

by

Mr. King Siu
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5.1 INTRODUCTION

The Battalion: Ground/Air Platforms – Detect, Classify and Identify (BGAP-DCI) breakout panel was tasked to evaluate technologies that would meet current and/or future military operational requirements at battalion level against conventional or unconventional enemies in urban terrains in varying climates. Battalion level operations would involve mission planning for pre-deployment, engagement, post assessment and sustainment, including command and control, continuous situational awareness, etc.

The panel was provided a total of 18 technology description sheets to evaluate. The base for evaluation was drawn from the proposed vignettes, definition for BGAP-DCI (below) and expertise and experience of the panel members. The panel consisted of technologists and military officers from various nations (see Annex attached). After an introduction of members, instructions were provided on the scoring (or voting) process. The voting process generally included a brief open discussion among members prior to each technology voting. Comment sheets were also collected for documentation after voting.

The panel members also agreed to quickly review other technology description sheets within other session areas. Two additional technology description sheets, 3 and 43, were added. A total of 20 technology sheets were assessed.

5.2 DEFINITION: BATTALION GROUND/AIR PLATFORMS – DETECT, CLASSIFY AND IDENTIFY

- **Detect Definition:** The discovery by any means of the presence of a person, object, or phenomenon of potential military significance.
- **Classify Definition**: To arrange or order as belonging to a particular group (e.g. man or vehicle, wheeled vs. tracked).
- **Identify Definition**: The determination of the origin, nature, and characteristics of a detected person, object, or phenomenon. This may be accomplished by various means including visual recognition, electronic interrogation, flight plan correlation, and the interpretation of acoustic information, behavior, and/or hostile action.

Sensors in this category are those that are primarily for detection, classification and identification but may also be used for other applications.

5.3 SENSING REQUIREMENTS: BATTALION AND AIR PLATFORMS DETECT, CLASSIFY AND IDENTIFY

In order to evaluate each technology according to their effectiveness in an urban operation, the following typical sensing/information requirements generated from studies of simulated urban operation vignettes (extracted from a "Results of IST-46 meeting 22-26 March 2004, The Hague"[1]) were considered on each technology:

1. Information on NBC(wmd) / possible ROTA incidents
2. Determine location of armed factions
3. Determine location of ethnic leaders
4. ELINT (COMINT) Cell Phone activities monitored 6. Imagery from rooftops, towers or on ground UGVs to vary monitoring locations
4. Obtain status of vehicle destruction operation Time of completion Presence and state of wounded, friend or foe location and state of destroyed vehicles
1. Information on NBC(wmd) / ROTA incidents
3. Need Blue Force Tracking Need adjacent unit Blue Force tracking in NRT
4. Need Red Force tracking (when known) Tool to track Red forces on overhead image, automatic following
Once tagged on overhead image, track! Snipers are tagged and already targeted 5. Need White Force Tracking (especially masses) 9. Zack advances to highway 2 (border of sector) (Vignette 2)
Good Red Force Tracking
Need routes from Base to Leg building that are concealed from Red SF taking shots to disrupt 11. Need 3D Blue force tracking (in building) (Vignette 3)
COs and Platoons may want floor that soldiers are actually on. Red Force 3D Tracking if possible
Particular interest in subterranean routes that may be used 3D “RED” Force tracking in the building and during Red egress of ALL other building occupants For aviation support 12. Overhead Imagery (Vignette 3) Full time live overhead imagery with Thermal Red vehicles hidden under overhead cover (houses/trees) Fires lit to confuse thermal sensors Require persistent overhead picture (i.e. from rotary wing)
Provide overhead imagery and surrounding area movement Neighboring street activities (i.e. movement of masses toward scene)

5.4 SENSING TECHNOLOGIES

These technologies could be categorized as acoustic sensing, optical sensing, and radar sensing.

The sensing Technology Description Sheets evaluated during this session were: **1, 4, 5, 6, 7, 9, 13, 16, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 3, 43.** The Technology Description # 3 is from the Platoon – Detect, Classify and Identify session panel and the Technology Description #43 is from Mapping session panel.

The group identified the following criteria to consider when assessing the technology description sheets:

- **Environment:** Can the sensor be used in all weather conditions and in the day and night?
- **Deployment:** How much time and effort does it require to deploy the sensor?
- **Operator skills:** How much skill does the operator need to setup, operate and interpret the sensor output?
- **Coverage:** What is the coverage of the sensor?
- **Timeliness of output:** How quickly can the sensor data be processed, interpreted and disseminated?
- **Cost:** What is the unit cost, (development cost) and also cost of deployment?
- **Power consumption, size and weight:** Can the sensor be readily deployed because of its size, power consumption and weight or will this limit its deployment?
- **Overt / covert:** Can the sensor be deployed covertly if required or is the sensor overt?
- **Technology Readiness Level (TRL):** How close is the technology to be being deployed in the field?
- **Sensor Fusion:** Can the output from the sensor be readily combined with other sensors to provide an improved capability?

5.5 SUMMARY

A total of 20 technology description sheets were evaluated. Most of these technologies offer either 2D or 3D active imaging solution for detection, classification and identification using optics, radars or fusion of two different types of sensors. The technologies include airborne sensors collecting data and either have onboard processing or down link to a ground station for processing as well as ground sensor systems. The description sheets provided performance parameters and even tried to present why a particular technology is better, but none attempted to discuss or provide a picture on the operational concept, describing how the sensor system would be deployed, how the data is being managed. That made the evaluation very difficult, in term of the military usefulness.

The sensors evaluated included Visible, NIR, Thermal, Hyper-spectral, radar, etc. Some of these sensors are questionable for the battalion level operation, i.e. short range performance, etc. In addition, timeliness of information provided by the sensors is critical for mission planning as well as for reaction. Another major challenge is the ability to interpret what you are looking at and the skill level of operators required. The ability to manage large/massive data and to understand full orthogonal or complimentary data are another massive task onto itself. All these would contribute to the success of a particular sensor application.

Additional challenges include sensors deployment (access of environment, overt/covert), support of sensors, management of sensor systems, C2 integration, communication links, etc, were not covered in the technology sheets nor evaluated as part of the technology, but need to be considered when a particular sensor is chosen. The communication link requirement was particularly noted as in the majority of cases the sensors will be operating in an environment where communication bandwidth is at a premium, and hence sensor remote processing or autonomous operation was also highlighted as important.

The panel noticed that there is a lack of NBC detection sensors (only two evaluated and there are no handheld devices) as well as sensors that would feed into or generate Sigint, Elint, Clnint, OSint, Human intelligent. The sensors for tagging were also lacking as well.

The following sensors were also noted as being of potential use in the Battalion Air Platform (DCI):

- High frequency Synthetic Aperture Radar (SAR);
- Through Wall Radar for building mapping and other applications (for example DARPA Visibuilding programme);
- 3D Laser radar;
- Electronic Surveillance Measures (ESM) in the urban environment;
- Sensor Fusion; and
- Electronic Intelligence (ELINT) systems.

Sensor fusion frequently came up in discussion although the participants did note that this term is often used as an overall term that has many meanings from highly complex sophisticated systems to relatively straightforward, pragmatic approaches. The consensus was that a “fused” sensor system would need to show an improvement against the criteria outlined earlier in this section.

The workshop participants also commented that a key consideration was whether a particular sensor was essential to an operation, given that a sensor has to show a clear benefit over an equivalent weight/size of ammunition. For sensor such as night vision systems this benefit is clear, however, for some of the other systems, this benefit is less clear.

Another important consideration that the workshop participants commented on was countermeasures. Although directly outside the scope of the workshop, this is increasingly becoming an issue if a complex sensor system can be disabled or countered by relatively simple means. A further issue is whether the sensor signature also provides a characteristic that can enable a system to be located.

Meeting Notes

	Pre-Operations	MCO	Post
Open Areas	Green	Yellow	Red
In-Building	Red	Red	Red
Underground	Black	Black	Red

- **Open Areas**

  Pre-Operations: Current sensor technologies have, in general, been developed for operation in open areas. Sensors can be pre-deployed on airborne platforms (including UAVs) or on the ground with timescales that are largely controlled by the blue forces, hence pre-operation requirements are generally met. There is still scope for improving resolution to allow automatic target recognition (classification and identification) and to further improve timeliness. (For example: UAV video surveillance).

MCO: This operation scenario is highly dynamic (in general, the timescales are less controlled by the blue forces) which placed further requirements on the sensors: it reduces the time to acquire data and secondly there is an increased requirement on timeliness of information. In addition, the platoon objectives may not prioritise sensor data collection. The sensor system will also have to transmit across a bandwidth limited communications link. There is a further requirement to classify between blue and red forces with high reliability. (For example: Blue force tracking).

Post-Operations: The threat is changed with a variable mix of hostile, non-hostile and unknown affiliations of people, over a wide area. In many cases the number of hostile people may be a very small proportion of the population, and threats cover IEDs, chemical and biological threats. This places additional requirements on sensor systems in that achieving appropriately low classification and identification error rates is challenging. Ideally the sensors should detect the planning of hostile acts before they are carried out, or in the very early stages of a hostile operation, placing further requirements on the sensors. (For example: detection of a suicide bomber in a crowd of people).

- **In-Buildings:**

  The requirement for urban operations is to cover a given area and provide accurate information to the Battalion level. This requirement is independent of whether the area is open, or covered by a significant proportion of buildings.

  This is a relatively new sensing requirement and hence is less well developed than sensors for operation in open areas. In this case there is a restriction on the types of sensor that can be deployed due to the environment, for example, optical sensors are limited by obscuration and low light levels, radar technologies are limited by propagation conditions that have to be taken into account.

  Pre-deployment: Operation of in-building sensors with large levels of stand-off performance (greater than 25 metres) is very limited currently, although certain research programmes are underway (for example DARPA Visibuilding).

  MCO: There are further developments on in-building sensors (also covered by DARPA Visibuilding and RDECOM STTW programme). Most current sensors are target acquisition type sensors rather than classification and identification sensors.

  Post-operations: This is similar to the issues raised in the previous section, but further complicated by operation in-building.

- **Underground:** The workshop did not address technologies for detection, classification and identification underground. However, sensing is challenging as in many cases there are very low light levels which makes image enhancement problematic, and is more difficult than operation in building. Pre-deployment is difficult. There is some research work ongoing in airborne sensors for underground mapping, but these have yet to report results. Operation of these sensors with suitable stand-off ranges and resolutions will be problematic. For ground deployed sensors then accurate positioning is difficult due to an absence of location methods. Underground sensing in post-deployment is rated as red since this can be carried out using remote ground vehicles, for example US Army Gladiator research programme.

Research Areas in Urban Environment

	Pre-Operations	MCO	Post	Technologies
Open Areas	• Red force tracking • Base of operations detection • Improved stand-off / resolution	• Red force tracking • Local processing (at low power) • Mesh networking • Reduced power consumption / size of sensors for UAVs • CBRN(E) detection • Improved timeliness • Improved stand-off / resolution	• Persistence Surveillance • Hostile vehicle detection • Suicide bomber detection • Vehicle borne device detection • CBRN(E) detection • Sniper detection	• SAR Radar • EO sensors • Stand-off CBRNE detection • Distributed CBRNE detection • CWD • Temporal processing / pattern detection
In-Building	• Base of operations detection • Red force tracking • Explosives cache detection • Improved stand-off / resolution	• Blue force tracking • Red force tracking • Base of operations detection • Explosives cache detection • Mesh networking • In-building comms • (Building mapping) • Maintain accuracy in building	• Persistence Surveillance • Sniper detection • Explosives cache detection • CBRN(E) detection • Base of operations detection	• STTW Radar / Imaging • EO Sensors • Acoustic • Distributed / Trace CBRNE detection • Temporal processing / pattern detection
Underground	• (Underground activity detection / mapping) • Red force tracking • Explosives / IED detection	• Blue force tracking • Red force tracking • Explosives / IED detection • Underground comms	• Persistence Surveillance • Red force tracking • Explosives cache detection	• GPR (Ground and UAV) • Acoustic • EO sensors • UGVs • Trace CBRNE detection

Notes:

- Note that requirements are broadly standard between open areas, in-building and underground.
- General requirements: improved stand-off, reduced power consumption, and size of sensors, and communication of information.
- Roles for battalion: Intelligence gathering (ELINT, SIGINT, HUMINT), support and planning of operations.

CWD: Concealed Weapons Detection

CBRNE: Chemical, Biological, Radiological, Nuclear and Explosives

5.5.1 Scenarios

Below is a summary of situations/scenarios where sensors can play a role in providing the suggested capability, but not necessary pertained to battalion level operations. The background planning, base protection and surveillance vignettes that are marked by a * were added by workshop members at the beginning of the discussion.

Background Planning*

- Acquisition of intelligence to support operations:
  - SIGINT (Signals Intelligence);
  - HUMINT (Human Intelligence); and
  - ELINT (Electronic Intelligence).

Deployment

- Mission Planning:
  - Imaging for mapping; and
  - Real time situational awareness to allow troop manoeuvre.

Reaction

- Ability to determine combatant, non-combatants, etc.:
  - Facial recognition;
  - Situation Awareness/background monitoring;
  - Changes; and
  - Tagging.

Offensive

- Ability to manoeuvre- deny or access of areas:
  - How things change over times;
  - Persistent sensing;
  - Underground monitoring;
  - See thru Wall/window;
  - Coordination/blue force tracking;
  - Remote listening;
  - Tagging; and
  - CM/CCM.

Patrol and Ambush

- Situation Awareness:
  - Situation/background monitoring;
  - Changes Monitoring;

- Security; and
- IED, Sniper etc.

Base Protection*

- Situation Awareness;
- Changes Monitoring; and
- Perimeter Protection/Security.

Surveillance*

Ongoing surveillance of an area to detect changes that may affect future operations.

5.6 COMMENTS ON EACH TECHNOLOGY

The comments are based on each Technology Description Sheet and provided by participants in the break-out session.

5.6.1 Technology Description 1 – Surveillance Visualization

Score Range: 1-4; Average Score: 2.5

Clarification on Technology

This technology uses staring EO camera (thermal or visual) to create 3-D imagery of a survey area.

Positive Points for the Technology

It would help operators manage the massive amounts of data received because it spatially locates the data in the area where it was taken. It can also help with spatial relations visualization (i.e. people running) Integration with IR would be good for night visualization. 3D representation is good planning and analysis tool.

Negative Points against the Technology

Set up requirements, i.e., Pre-load 3 D model, pre-emplaced cameras, accuracy of location of cameras, synchronization of cameras, hard to take a 2-D image and map it on a 3-D model – this may not be practical based on zoom, aspect angle etc. It takes time to define the 3-D model.

For tactical, CCTV may not be available during initial deployment phase (vignette 1).

General Impression on the Technology

This technology is useful for mission planning as well as a tool to evaluate for events and activities that had happened.

5.6.2 Technology Description 4 – Hyperspectral Imager in Visual/Near-Infrared

Score Range: 1-4; Average Score: 3.14

Clarification on Technology

This technology uses hyperspectral sensors to sample radiation within visual near IR bands.

Positive Points for the Technology

The technology introduces a potential for new algorithms and processing methods for detecting and classifying typically difficult objects, i.e., detecting camouflage, man-made material, etc. It is useful for detailed analysis.

Negative Points against the Technology

Weather conditions limit performance. It requires daylight. Need platform application requirements – current system is quite large. High bandwidth! Autonomous classification doesn't exist. Algorithm processing is a large requirement, with some concerns over timeliness of information from the sensor.

General Impression on the Technology

The technology is useful, but needs night capability (broadband Vis/NIR illumination) as well some type of bandwidth reduction/compression technique.

It could be used as a tool for forensic and detailed analysis for very specialized users.

5.6.3 Technology Description 5 – Free Space Optical Communication

Score Range: 2-4; Average Score: 3.23

Clarification on Technology

Optical communication based on same technology as fibre-optic communication, but in free space.

Positive Points for the Technology

Modality lends itself very well to accommodate for high bandwidth requirements. It could be used on ground platform (including UGV) to high altitude airborne platforms. Good alternative that satisfies covert requirements. Works better transmitting up rather than along the ground. It could cover large area by reflecting off the atmosphere.

Negative Points against the Technology

Technology is impartial for deployment on a small UAV (weight issues/power). It also has limited capability in complex terrain due to scattering. Difficulties with smoke, fog, rain. N-LOS application is less covert. It can't ID on its own.

General Impression on the Technology

This technology is limited by weather and to line of sight, but a good covert communication scheme.

5.6.4 Technology Description 6 – Optical Sight Detector

Score Range: 1-4; Average Score: 2.54

Clarification on Technology

This technology uses short transmitted pulse to detect the reflection of the optical radiation from the optical sights.

Positive Points for the Technology

It detects snipers that are looking at you. Sniper sight detection can detect a sniper before he shoots at you!! Can detect surveillance by red force (i.e. binoculars and other scopes).

Negative Points against the Technology

Technology may be susceptible to clutter in an urban environment (i.e. false alarms due to headlights). Limited detection capability (detection requires that the sight is pointed at the look direction). FOV limitation means that it requires a long time to scan a particular area of interest, probably more useful when you know high probability areas where snipers are likely to engage. Probably not a technology that should be evaluated on the Battalion level (should go to Platoon level evaluation). Vulnerable when emplaced.

General Impression on the Technology

May not be useful at Battalion level.

5.6.5 Technology Description 7 – Portable Low Cost Radar Sensor for Imaging and Communication

Score Range: 1-4; Average Score: 2.62

Clarification on Technology

Leverage Frequency Modulated Continuous Wave (FMCW) or Pulsed Ultra wide Band (UWB) radar/sensors to form network sensors for situation awareness, mapping and communication.

Positive Points for the Technology

There is potential benefit for miniaturized networked radar sensors in a complex environment.

Negative Points against the Technology

Questions about deployment and/or on various platforms surfaced as major concern. If small, it may suffer from limited resolution and wide beam width. It could be short range. Probably won't get a lot of information from this sensor over the wide range of application claimed – Description shows that item is doing a lot of different things (multi-functional).

General Impression on the Technology

Technology Description not detailed enough. There are no details on how it works.

What is the network range? What is the proposed size of the unit and network? What is the cost per unit? What is the classification scheme?/Data processing?/Real time display?

5.6.6 Technology Description 9 – Multi/Hyperspectral Thermal Imager

Score Range: 2-4; Average Score: 2.42

Clarification on Technology

Multi-spectral thermal sensors sense emitted energy from objects within the MWIR and/or LWIR domains.

Positive Points for the Technology

Good planning tools for mapping, recon, surveillance at battalion level. It has an incremental benefit when compared to previous systems (earlier concept sheets in this area).

Negative Points against the Technology

High bandwidth requirement, sensor processing is an issue because of computationally intensive processing that is required, autonomous feature space extraction and classification might be difficult. Weight specifications and volume specifications are extremely broad (need further clarification). UAV use is limited due to size, weight, power, etc. Could be expensive!

General Impression on the Technology

It is specialized equipment that requires skilled user to interpret data. Size, weight, power, high bandwidth processing and cost vs. benefits are considerations for development.

5.6.7 Technology Description 13 – Thermal Surveillance with Advanced Functionality

Score Range: 3-5; Average Score: 4.25

Clarification on Technology

High resolution LWIR imager system incorporated on a UAV with geo-localization system and link to ground station for real time signal processing.

Positive Points for the Technology

It is an essential capability for a UAV (categorically improves a needed capability). The proposed technology can be combined with 3-D models and maps. The current resolution of the optics should be sufficient.

NOTE: Evaluated and scores are based on thermal imager on platform with improved performance.

Negative Points against the Technology

Technology needs additional capabilities such as, auto focus, auto gain and a higher dynamic range. Automatic operation is beneficial, but requires years of development. It is an enabled technology for large UAV not small UAV (as proposed) for present.

General Impression on the Technology

It is essential technology for any UAV. Real time imagery processing from linked moving platform is being developed, may be ready in 5 years. **Small UAV with high performance uncooled thermal Imager is the ultimate answer for information gathering at battalion level operations.**

5.6.8 Technology Description 16 – Mono and Bistatic Low Frequency SAR for Situation Awareness

Score Range: 2-4; Average Score: 3.33

Clarification on Technology

The technology involves bi-static low frequency radar to penetrate vegetation and building materials as well as improve target to clutter ratio.

Positive Points for the Technology

This approach should give you penetration through foliage as long as the frequency is low. It could also penetrate building structures with low frequency operation. Clutter reduction capability is also a plus.

Negative Points against the Technology

Image interpretation is difficult because images are taken from long stand-off range and devoid of the required resolution. The ability to discriminate will be low and not conducive to ATR applications. Suitability for small UAVs is questionable. 50cm (proposed performance) resolution may not be adequate for target classification.

General Impression on the Technology

Some of the proposed performances are beneficial for mapping and planning purpose. Deployment on small UAV is questionable for present. Looking into building and ground are criteria for the technology, thus discrimination is critical.

5.6.9 Technology Description 22 – CUIRACE: Foliage Penetration

Score Range: 1-4; Average Score: 2.08

Clarification on Technology

Using Pulse Doppler Waveforms technology to detect vehicle or helicopter hidden behind a mask or foliage.

Positive Points for the Technology

NLOS is a plus.

Negative Points against the Technology

The technology needs to address the signal processing methods to mitigate against multipath in urban environment.

General Impression on the Technology

There is not enough information on how it works. The technique of NLOS capability in urban environment that would detect and classify vehicles and avoid clutter is not clear. It has very limited usefulness in urban operations, but may applicable to outskirts of a city.

5.6.10 Technology Description 24 – Active Imaging System

Score Range: 4-5; Average Score: 4.33

Clarification on Technology

An active imaging system combines with a solid state laser diode array illuminator with a range-gated intensified camera.

Positive Points for the Technology

Night capability coupled with high resolution is a benefit. Technology enables depth scanning. Ability to range gate and obtain improved performance. There is am added benefit of retro reflection to detect optical sights.

Negative Points against the Technology

Not eye-safe at ranges < 50m, but can be resolved by using 1.5µm wavelength and corresponding detector.

General Impression on the Technology

It is useful and supports planned operations. It is more applicable at Platoon level.

5.6.11 Technology Description 25 – Airborne Laser Scanner (ALS)

Score Range: 2-3; Average Score: 2.67

Clarification on Technology

The ALS system consists of a laser rangefinder, a scanner, a position and orientation subsystem (GPS 7 INS) and a processing control subsystem used in airborne platform.

Positive Points for the Technology

For Detection, Classification and ID, 3-D Laser imagery is very conducive to robust feature extraction for classification and ID. It is an enable technology for change detection application by comparing prior imageries with updated imageries to look for changes.

Negative Points against the Technology

This technology is primarily for mapping. It is computationally intensive – not easily executed in real time.

General Impression on the Technology

This technology provides 3-D maps for planning purpose. Current systems are heavy with less resolution. Focal Plan Array ALS system will reduce size and power consumption with increased resolution and data capture rate.

5.6.12 Technology Description 26 – Near Infrared Sensor (NIR)

Score Range: 2-3; Average Score: 2.42

Clarification on Technology

NIR camera that is applicable to CCD type sensors.

Positive Points for the Technology

There is a potential application in small sensors for unattended ground sensor network. Man-made objects tend to stand-out from natural background at the proposed wavelengths (0.9 to 1.7 µm or 2.5 micron) which is potential for IED detection.

Negative Points against the Technology

Short range operation and need for emplacement limits utility of this particular technology. Application and purpose of this technology/device are not clearly proposed.

General Impression on the Technology

Why doing it or what benefits would yield over other IR sensors?

5.6.13 Technology Description 27 – Hyperspectral Imagery (Visible and Infrared)

Score Range: 1-4; Average Score: 1.5

Clarification on Technology

Visible system detects reflected light and measures spectral components.

Positive Points for the Technology

The technology can be a highly capable and highly specialized sensor with proposed application for hazardous gaseous detection.

Negative Points against the Technology

It requires specialized skills to interpret information. Not a lot of information provided.

General Impression on the Technology

Wide range in proposed cost $ .5M to $5M, it could be cost prohibitive. Need more information to evaluate.

5.6.14 Technology Description 28 – EO Imagery (Visible)

Score Range: 5; Average Score: 5

Clarification on Technology

Visible band imagery sensor.

Positive Points for the Technology

An absolute needed capability!

Negative Points against the Technology

ATR algorithm development can further enhance detection, classification and ID for our applications. Bandwidth limitations: should drive to enhance lossless compression techniques. Need light source!

General Impression on the Technology

Not a new technology, such as high definition video cameras.

5.6.15 Technology Description 29 – Image Sensor Fusion for Soldier-Borne Applications

Score Range: 1-3; Average Score: 2.5

Clarification on Technology

The technology suggests investigating digital signal processing image processing techniques and fusion algorithms for soldier applications.

Positive Points for the Technology

It is assumed that the proposed fusion package of 2 sources (Vis/NIR) is for increase rang and sensitivity. It could be useful to the battalion if utilized by specialist teams for information gathering applications.

Negative Points against the Technology

There is not enough information to evaluate. Concept does not clearly describe the added benefits of the sensor fusion.

General Impression on the Technology

The technology is presented as a soldier wearable system, therefore is more pertinent to evaluation by the Platoon group.

5.6.16 Technology Description 30 – Mid Wavelength Infrared Sensors (MWIR)

Score Range: 3-5; Average Score: 3.89

Clarification on Technology

MWIR in wavelength 3.3 – 5.0 µm that offers near 100% transmission with the added benefit of lower ambient background noise.

Positive Points for the Technology

MWIR is useful for night operations. Improved 3-5 µm wavelength is more useful in short range compared to 8-12 µm, i.e. urban etc. It is suitable for emplacement in UAV, applicable to the vignettes, small package and light weight, people detection. Higher operating temperature is a plus.

Negative Points against the Technology

Target comparison for classification and recognition is a challenge. It needs special training to interpret the targets.

General Impression on the Technology

It is useful, but interpretability of MWIR is unclear, unclear to how sensitive of these systems are, Contrast – How good is the contrast?

5.6.17 Technology Description 31 – Compact Atmospheric Sounding Interferometer (CATSI)

Score Range: 1-4; Average Score: 3

Clarification on Technology

Passive standoff long wave IR (7-14 µm) chemical vapors sensor.

Positive Points for the Technology

It addresses NBC requirement.

Negative Points against the Technology

The proposed size and weight (<50 kilos) as well as integration are major concerns. It is specialized equipment that needs to be integrated to pass on collected and analyzed data. Is it an automated process? No sensitivity data provided. Additional performance information, such as Standoff, false alarm, detection range, etc., is not required to assess.

General Impression on the Technology

It is a needed capability. The proposed system is bulky. Operational concept and performance information are not provided.

5.6.18 Technology Description 32 – Short Wave Infrared (SWIR) Sensors

Score Range: 2-4; Average Score: 2.5

Clarification on Technology

SWIR detectors and camera provide better resolution than thermal camera and can see through glass.

Positive Points for the Technology

It has improved resolution compared NIR. It is applicable for use as unattended ground sensors.

Negative Points against the Technology

It is short range. It does not operate below 5° C or above 35°C. It has limited field of view and required some light. Does it really provide a true night capability? In-door application is questionable? Higher cost compared to digital camera.

General Impression on the Technology

It is a short range device. It is not a battalion level type equipment.

5.6.19 Technology Description 3 – Combined Millimetre/Optical Surveillance System

Score Range: 2-5; Average Score: 3

Clarification on Technology

The system consists of a coherent millimetre wave Pulse-Doppler multiple channel radar operating at 220GHz combined with a passive optical system.

Positive Points for the Technology

The combination of low resolution area surveillance with a high resolution interrogation (classification/ID) system is a good balance, but why 220 GHz? – possible for Detect weapon?

Negative Points against the Technology

It has a limited range (~1km) and is for static application only. A lower frequency can achieve similar performance with better range. Fog would limit the operation of optical system.

General Impression on the Technology

Potential for base surveillance and monitoring.

5.6.20 Technology Description 43 – 3D Ladar for UAV (or Ground Vehicle)

Score Range: 4-5; Average Score: 4.125

Clarification on Technology

Staring 3D Ladar at 1.5µm wavelength.

Positive Points for the Technology

It offers 3-D with high resolution, Good target ID capability, and classification in term of contrasting tree, person and other types of objects.

Negative Points against the Technology

Weather limitation as well as see thru the wall. It is focused area instead of wide area surveillance.

General Impression on the Technology

3D offers better classification and can be done automatically.

Chapter 6 – MAPPING

by

Mr. Mike Lewis

6.1 INTRODUCTION

In urban operation forces need to be well prepared to conduct operations against conventional or unconventional enemy forces in all types of terrain and climate conditions across the complete spectrum of conflict (major theatre war, smaller-scale contingency, and peacetime military engagement).

To do this, forces employ a multi-level, integrated suite of intelligence, reconnaissance, and surveillance assets with assistance of several kinds of sensors. The entire information collected by the sensors provide the force commanders with a unique capability to visualize, describe, and direct the brigade through the full spectrum of operations and terrain in which the unit may be operating. Of extreme importance to the commander is the availability of accurate maps.

Maps for use in the direction of military actions differ from commercial maps in that a higher accuracy is required. Although commercial maps are accurate as to the positioning of features they are not accurate in respect of road widths. In general on commercial maps road widths are exaggerated in the interests of clarity and legibility. This means that commercial maps are not suitable for determining firing arcs or for determining if roads are wide enough to allow the passage of military vehicles.

Additionally commercial maps may not show the detailed layout of industrial areas or the location of such features as cell-phone base stations. The latter, along with telephone exchanges, are not only important in the control of communications but may also be used as illuminators for ad hoc multi-static radar systems.

The previous paragraphs have concentrated on above ground physical features however the military mapping requirement was considered to be wider than this and also included within building and below ground information.

During the session a further important aspect of underground information emerged. This concerned the load bearing characteristics of the roads and their suitability for the passage of heavy vehicles. A further consideration was the condition of the surface itself and whether the passage of heavy vehicles would destroy the surface.

6.2 DEFINITIONS

In this session we focused our thoughts on sensing technologies which could be useful for locating objects in battalion/air platform level (Mission plan and command) as well as platoon level (Operation). The definitions adopted to conduct this session were as follows:

- **Mapping Definition:** Determining the location and state of buildings, roads, utilities, routes (non-moveable objects) and locating them accurately in an absolute coordinate system.
- **Above Ground Definition:** Above the surface of the earth but not contained within a building or other structure.
- **Within Buildings Definition:** Within a building or structure on the surface (includes the basement of the building), does not include the roof.
- **Below Ground Definition:** Below the earth’s surface, not the basement of a building that exists above ground. For example: sub-way system, caves, facilities, etc.

6.3 ASSUMPTIONS

In evaluating the various sensor technologies available for mapping it was assumed that the following considerations had been met or addressed:

- Accurate geo-location system available.
- Inertial navigation units to keep track of sensor pointing and platform movements.
- Appropriate Signal Processing and Data Fusion.
- Relevant Data Links available.
- Interoperability.
- Security.

There are almost certainly implications on both sensors and the above items

6.4 SENSING TECHNOLOGIES

Sensors Evaluated: 4, 7, 9, 11, 13, 16, 25, 27, 30.

6.5 SENSING REQUIREMENTS: MAPPING

Some of the requirements discussed for sensors in this session were as follow:

1. Request for a three-dimension map of the building (INFRASTRUCTURE: including stairs, windows, underground and all possible details and SERVICES: electricity, gas, water supply) – the viewing must be as realistic as possible and “change detection”-oriented. Moreover: air-conditioning network – for NLW (gas) use purpose
2. Request for information on non-firing zone inside the building (national archives?)
9. Request information in a large area (perimeter) around the scene to discriminate the event
10. Request a local survey of the zone of interest (accident)
5. Knowledge on potential flashpoints
6. Imagery from rooftops, towers or on ground UGVs to vary monitoring locations
2. Determine location of key cultural sites
3. Determine location of key city schools
4. Determine location of Legislative Building and Court House
5. Determine location of AL plant and Centre Business Park
6. Information on possible ROTA locations
8. Need communications coverage in AO
Dead spots that restrict operations should be augmented by placement of relays (ground/building/aerial)
12. Need 3D and subterranean model of city
13. Mapping of building Need building maps Need subterranean routes in for blue forces Need subterranean routes out for red forces Need subterranean maps in vicinity

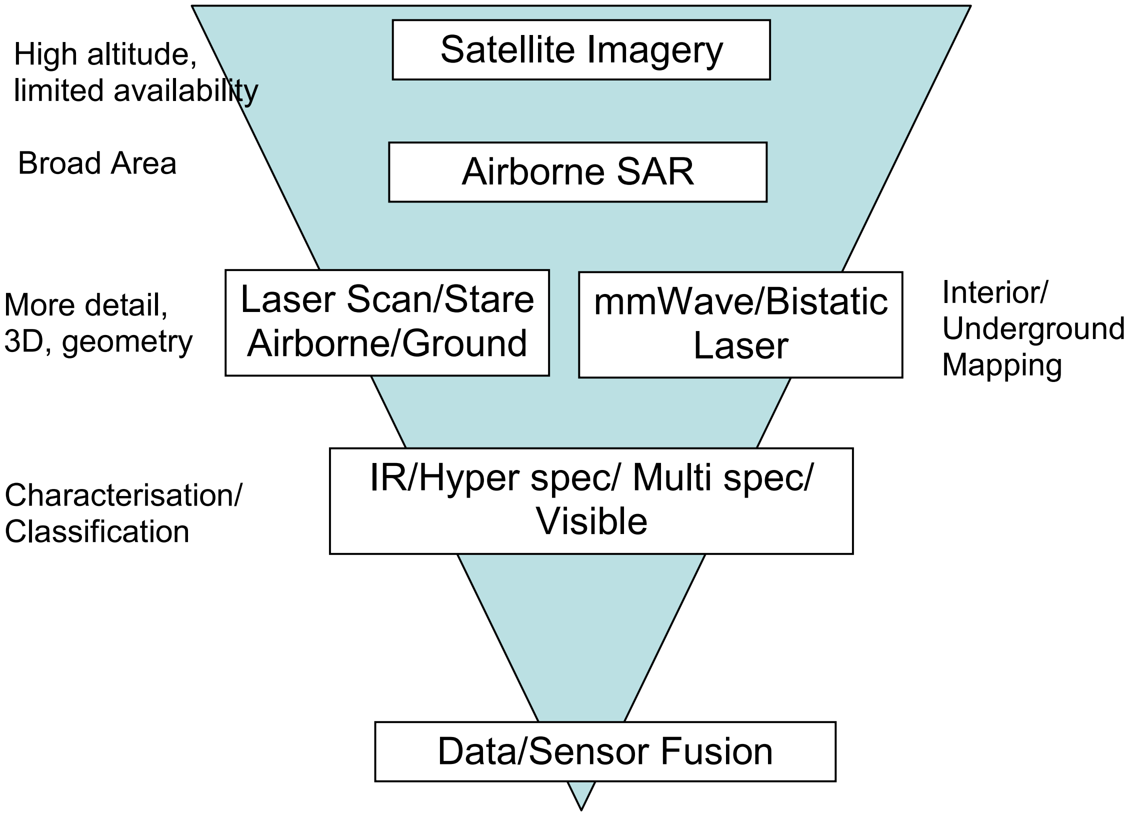
23. Require time sensitive targeting (targets of opportunity, moving targets)
1. Critical points surrounding event site to isolate
3. Mapping of building. Need building maps. Need subterranean routes in for blue forces. Need subterranean routes out for red forces. Need subterranean maps in vicinity
6. Information on Contact on Rt 2. Need RT overhead imagery over engagement area. Need possible new Red Aves of Approach
8. Identify buildings from which Red will defend from
9. Identify buildings that we can defend from. Buildable database over time, but now becomes punctual
12. Locations of local services Police, local government

8. Terrain Report of possible location of threats + difficult access, ... (surrounding of camp)
1. Information on NBC(wmd) / possible ROTA incidents
5. Knowledge on potential flashpoints
6. Imagery from rooftops, towers or on ground UGVs to vary monitoring locations
1. Require information about the enemy forces Crossing capabilities Require information about likely routes/ way of approach the enemy forces may use to enter our AOR Times the enemy needs to reach certain positions

6.6 ASSESSMENT OF CURRENT SENSOR TECHNOLOGY

	Pre-Combat	MCO	Post-Combat
In the Open			
In Buildings			
Underground			

6.6.1 Summary



The various sensing technologies for mapping, including satellite imagery which was not considered, falls into a hierarchy as indicated by the above diagram.

In general radar, SAR in particular, appears to provide standoff mapping capability but with poor resolution. The standoff capability makes it suitable for use at the planning stage although vital information such as the condition of road surfaces cannot be obtained.

LADAR, IR in various bands and EO provide more accurate information but require closer range and are only suitable for areas over which control has been obtained. There is clearly no means of obtaining maps of building interiors nor of underground features since these technologies are not able to penetrate building materials.

Whilst none of the technologies considered can be called a solution to the mapping problem it is possible to recognise fruitful lines of development. The greatest capability gap, however, appears to concern remote mapping of building interiors and underground facilities.

In respect of building interiors the use of low frequency, 100MHz – 2GHz, bistatic radar has been proposed and was mentioned in the presentations [4].

Underground mapping and detection of deeply buried targets was discussed by Wicks [5] in a keynote presentation at a recent IET Waveform Diversity Forum. He proposed the use of 3D Tomography. The sensors are mounted on a shell or other ground penetrating projectile.

3D RF Tomography would appear to be a significant candidate in this area.

6.7 COMMENTS ON THE TECHNOLOGIES

6.7.1 Technology Description 4 – Hyperspectral Imager in Visual/Near-Infrared

Clarification on Technology

Hyperspectral VNIR sensors sample the incoming reflected radiation in many bands within the visual and near infrared domains. Mounted on UAV/UGV. Present systems scanning.

Positive Points for the Technology

This equipment was seen as good for mapping based on material characteristics of grass/buildings etc., and as such could be useful for detecting the condition of road surfaces In addition it had potential for the detection of materials used in the construction of doors etc. There was also the capability of detecting structural anomalies and classifying them.

Negative Points against the Technology

It was noted that operation was not real time since a long processing time was required and that it required a large bandwidth and had high power consumption. The equipment required experts to interpret the data and performance was limited by weather conditions at longer ranges.

General Impression of the Technology

In general it was felt that the technique would be good for time insensitive targets and for large scale change detection. It could also be used for cueing other sensors.

Because of the non-real time operation the equipment seemed to be more appropriate for use in the mission planning stages of an operation. In these circumstances capability and resolution would be more important than size and weight.

6.7.2 Technology Description 7 – Portable Low Cost Radar Sensor for Imaging and Communication

Clarification on Technology

The concept of this technology is to use a number of low cost radar sensors for both radar imaging and mapping (LOS, NLOS or through-the-wall) and communication within a network for surveillance.

General Impression of the Technology

Although this was clearly a useful technology it was not seen as being appropriate to mapping as here defined.

6.7.3 Technology Description 9 – Multi/Hyperspectral Thermal Imager

Clarification on Technology

Multispectral thermal sensors sense emitted energy from objects in several bands within the MWIR and/or LWIR domain.

General Impression of the Technology

Extends 4 into longer wavelengths and is not restricted to daylight. In the same manner as 4 it gives good terrain/geological information but the example quoted has lower resolution than 4.

6.7.4 Technology Description 11 – Long Wavelength Infrared (LWIR)

Clarification on Technology

Long Wave IR sensors sense emitted energy from objects in the 8-12 micron waveband.

General Impression of the Technology

Useful for real time surveillance when mounted on a small UAV. The technology is probably useful for mapping but is better for soldier use since it has the advantage of being small. Could be used for the detection of targets of opportunity but not wide area, high resolution mapping since limited information is available due to the narrow bandwidth.

6.7.5 Technology Description 13 – Thermal Surveillance with Advanced Functionality

Clarification on Technology

High performance thermal imager (probably supported by a high resolution EO camera in the visual) in an UAV with a highly improved geo-localization system, i.e. advanced gyros to keep thorough track of sensor pointing and platform movements. On-board advanced signal processing for autonomous reconnaissance. Real time signal processing on the ground. Merging of sensor information and 3D models and maps. MMI with presentation of evaluated and emphasized information in order to facilitate for the operator.

General Impression of the Technology

This sheet is a good description of a typical sensor system configuration and is applicable to any sensor system. It does not introduce any new sensor technology.

6.7.6 Technology Description 16 – Mono and Bistatic Low Frequency SAR for Situation Awareness

Clarification on Technology

High resolution synthetic aperture radar images can be reached using a large bandwidth and aperture. Low frequency radar has good penetration in vegetation and most building materials. Bistatic configurations can be used to improve the target to clutter ratio.

Positive Points for the Technology

Good to Excellent for wide area mapping and has all weather day/night capability. It is usable in a standoff mode at up-to 10km range. It produces same day results which makes it good for initial planning purposes.

Negative Points against the Technology

The disadvantages are that artefacts are generated in urban canyons which needs more research. More fundamentally, VHF SAR has poor resolution (2.5m) thus limiting map accuracy particularly if such considerations as firing arcs need to be determined.

General Impression of the Technology

Can be used in standoff mode thus can be used for initial planning although resolution is poor. Penetration is good and thus may be used for remote mapping of building interiors, particularly in the bistatic mode. May be suitable for remote underground mapping but further research is needed.

6.7.7 Technology Description 25 – Airborne Laser Scanner (ALS)

Clarification on Technology

An Airborne Laser Scanner (ALS) uses a laser range finder, scanner, position (GPS) and orientation subsystem (INS) to capture detailed geometric information of the natural environment in terms of 3D point clouds.

Positive Points for the Technology

Good to Excellent for localised precision mapping and should be seen as complementary to SAR. It is possible to infer the nature of a building, e.g., factory, hotel. It also provides an indirect and coarse indication of material via the strength of the laser pulse return signal (wavelength dependent).

Negative Points against the Technology

ALS is not stand off and thus requires a degree of control of the area being surveyed. It has Night/Day but not all weather capability.

General Impression of the Technology

Produces Good 3D information, information on urban clutter (trees, street furniture, lamp posts. etc.). Could be used to obtain a good determination of your camp structure for defensive placement of sensors. The radar gives more detail on cultural and social objects, key points in a city and centres of gravity than can be achieved with SAR.

6.7.8 Technology Description 27 – Hyperspectral Imagery (Visible and Infrared)

Clarification on Technology

Visible system detects reflected light, measures spectral components. IR system detects thermal radiation, measures spectral components. Combines imagery with spectral content for discrimination, relies heavily on real-time processing.

General Impression of the Technology

This has, in effect, been covered by sheets 4 and 9 and does not introduce any new technology.

6.7.9 Technology Description 30 – Mid-Wavelength Infrared Sensors (MWIR)

Clarification on Technology

The medium wavelength IR (MWIR or MIR) band (3.3-5.0 μm) also offers nearly 100% transmissions, with the added benefit of lower, ambient, background noise.

General Impression of the Technology

This has, in effect, been covered by sheets 4 and 11 and does not introduce any new technology.

6.7.10 Technology Description 33 – Active Millimeter-Wave Sensor

Clarification on Technology

Transmit millimeter-wave signal that interact with differently with organic and non-organic material. Detects the presence of a building, vehicle and people. Uses very low transmitted power.

Positive Points for the Technology

Short range high resolution in 3D. Millimeter wave radar is also useful for the detection of hidden weapons and possibly of IEDs.

Negative Points against the Technology

It is only usable for short range local mapping which restricts it to soldier use. It also has poor azimuth resolution and needs improved image processing. Interpretation of the display is not easy and requires a trained user. Performance depends on the control of false alarms.

General Impression of the Technology

This has potential use for mapping within underground facilities and building interiors and may be of use for surface dynamic route planning. It may be of use mounted on a UGV or UAV.

6.7.11 Technology Description 36 – Volumetric Sensor for Mobile Robotics in Complex Terrain

Clarification on Technology

The volumetric sensor is a compact sensor head that combines a wide baseline stereo camera and a laser scanner with a full 360 degree azimuth and 55 degree elevation field of view.

Positive Points for the Technology

Allows a robot to view and manage overhanging obstacles as well as obstacles located at ground level.

Negative Points against the Technology

Their may be problems in tunnels due to the active illumination warning the red forces.

General Impression of the Technology

Good for mapping the interiors of buildings, tunnels, sewers. The good resolution also allows mapping of the exterior geometry of buildings.

6.7.12 Technology Description 39 – Ground Penetrating Radar

Clarification on Technology

Ground penetrating radars (GPR) work in 100 MHz –2 GHz regime where the penetration of radar waves into the ground and concrete building structures often is good.

Positive Points for the Technology

GPR can be used for mine detection and for location of tunnels, pipes, cables, metallic and other objects. Hidden layers, structures and cavities below the ground level or behind walls can also be imaged.

Negative Points against the Technology

The disadvantage is that data gathering is slow and may need several hours under hostile conditions. The resultant maps require expert interpretation.

General Impression of the Technology

Widely used for sub-surface mapping. (Archaeology, Police investigations) and is useful for determining the quality/solidity of roads. Resistivity measurements should also be considered.

6.7.13 Technology Description 40 – Multi-Sensor Chain for Border Surveillance

Clarification on Technology

The system consists of several slightly elevated radars and optical sensors forming a chain searching an area around a borderline. The radar guide high resolution optical systems for threat analysis. Search results are communicated through the sensor line to suitable located command posts.

General Impression of the Technology

This was considered to be more applicable at battalion level for surveillance.

6.7.14 Technology Description 43 – 3-D Ladar for UAV (or Ground Vehicle)

Clarification on Technology

3-D laser radar (ladar) gives a high resolution 3-dimensional image. Mounted on small UAV/UGV. Staring 3-D ladar at 1.5 µm wavelength.

General Impression of the Technology

3-D ladar could be used for mapping underground structures, interiors of buildings, exterior geometry of buildings or urban clutter. It produces high resolution local mapping and should be compared with 25 and 36. This represents a significant technological breakthrough compared with scanning systems.

In respect of building interiors the use of low frequency, 100MHz – 2GHz, bistatic radar has been proposed and was mentioned in the presentation by Baker [4].

Underground mapping and detection of deeply buried targets was discussed by Wicks [5] in a keynote presentation at a recent IET Waveform Diversity Forum. He proposed the use of 3D Tomography. The sensors could be mounted on an air platform or via a shell or other ground penetrating projectile.

3D RF Tomography would appear to be a significant candidate in this area.

Chapter 7 – CONCLUSIONS ON SENSOR UTILITY FOR URBAN OPERATIONS

7.1 RESULTS FROM PREVIOUS CHAPTERS

In order to gain a good understanding of the conclusions, we look back at the assessments given in earlier chapters. This time, however, we'll look at them across phases of a conflict and within a specific regime (in the open, inside buildings and underground).

7.2 PHASES OF A CONFLICT

Not much in the way of trends can be seen from one phase to another. As the conflict progresses the military gains greater access and freedom of movement. This access increases their ability to survey areas of interest. However, increases in uncertainty that come with stability operations, namely separating hostile forces from civilian populations, further increases the level of difficulty. In the opinion of this team, those increases in uncertainty do not fully counteract the increased access to difficult areas.

7.2.1 Pre-Conflict

	Battalion		Platoon		
	Detect and Track	Identify	Detect and Track	Identify	Mapping
In the Open			NA	NA	
Buildings			NA	NA	
Underground			NA	NA	

Clearly, of most utility during this phase of an operation is range. The ability to find targets, determine their identity and purpose, and to find routes to points of interest from great distances, is vitally important. During pre-conflict operations, military forces have limited or no access to hostile areas. Therefore they must rely on sensors which can do the job from standoff distances.

High on the list of useful sensors is radar: both synthetic aperture radar (SAR) and ground moving target indicator (GMTI) radar. These sensors can look deep into enemy territory to find objects of interest. SAR has some ability to provide resolutions sufficient for identification. While EO sensors have much better resolution they are not capable of the ranges required for the early missions. However, SAR can be limited by multi-path propagation issues in the urban environment. All sensors will suffer from limited line-of-sight when trying to locate and identify targets from standoff ranges. Clearly sensors aboard surveillance satellites will be required (this was not addressed during this study).

7.2.2 Major Combat Operations

	Battalion		Platoon		
	Detect and Track	Identify	Detect and Track	Identify	Mapping
In the Open					
Buildings					
Underground					

During major combat operations (MCO) the level of difficulty for sensors increases with the convergence of opposing forces on the battlefield. Separating friendly from hostile from neutral in a dynamic city environment presents significant challenges. Some of this is offset by the ability to place sensors as Blue forces move through the battlespace holding ground or gaining air superiority.

Electro-optic sensors begin to be much more effective during this phase of a campaign. The ranges will be shortened. Given the limited line-of-sight for both air and ground platforms, systems will have to be close to sense their targets allowing EO sensors to be close enough to bring to bear their significant resolution abilities. TTW imagers will increase their utility so long as they're portable enough to be carried by a soldier or can work at enough stand-off distance to be carried by a vehicle.

7.2.3 Post-Conflict

	Battalion		Platoon		
	Detect and Track	Identify	Detect and Track	Identify	Mapping
In the Open					
Buildings					
Underground					

In post-conflict, contingency, peace keeping and peace enforcement operations the level of difficulty goes up but so does access to areas of interest. Blue forces have nearly unlimited access to areas of interest to place sensors and to do persistent surveillance. Identification is hampered by the unknown identity of hostile forces. They are no longer uniformed armies. While access and timeline do improve the situation, they do not raise the level of difficulty above yellow in most cases.

All sensors find utility during this phase of a conflict. Because blue forces are no longer limited in access all sensor modes can be employed. In fact, because of the difficulty of finding hostile forces and separating them from the population in general, all modes need to be used and combined to improve accuracy. Methods for exploiting massive amounts of information must be found or risk drowning decision makers in input.

7.3 CONFLICT REGIME

7.3.1 Open Areas

	Battalion		**Platoon**		
	Detect and Track	**Identify**	**Detect and Track**	**Identify**	**Mapping**
Pre			NA	NA	
MCO					
Post					

Clearly this is something we're good at – finding and identifying targets in the open. We have lots of sensors to bring to bear for targets in the open. Only when we try to identify hostile forces from standoff distances do we start to run into the limits of our ability to produce high-resolution images.

Radar, EO, LADAR, acoustics, and many other sensors are designed to target military sensors on an open battlefield. An exhaustive list of sensors with utility in open areas would be long. There is a significant legacy of sensors for these types of targets. The current challenge is to get current sensors to work together, more autonomously, and at longer stand off ranges.

At the soldier level, existing EO systems are sufficient to provide detection and identification of hostile forces. While not perfect, given the short distances in an urban setting, these systems provide good information for a soldier.

7.3.2 Buildings

	Battalion		**Platoon**		
	Detect and Track	**Identify**	**Detect and Track**	**Identify**	**Mapping**
Pre			NA	NA	
MCO					
Post					

It is readily apparent from the above table that things are much better at the platoon level than at the battalion. The soldier problem is much more short range – detecting and identifying people and targets before going into a building and once inside. When determining the contents of a building from standoff becomes the mission (for battalion forces and air platforms) the problem gets much worse.

3D LADAR provides high fidelity mapping information of the outside dimensions of a building. It can also be vehicle mounted to look into windows and map rooms visible through those windows. IR systems can be used to look for heat sources, to a limited extent, within a building. TTW radar sensors are beginning to show improvement in providing information within a building from standoff distances (for example, DARPA's Visibuilding program). Acoustics and laser vibrometry can also be used to detect the presence of people and machinery inside the building.

None of these sources answers all the questions. Together they start to make a pretty good picture. A lot of effort still has to go into concentrating those sensors onto the building.

7.3.3 Underground

	Battalion		Platoon		
	Detect and Track	Identify	Detect and Track	Identify	Mapping
Pre			NA	NA	
MCO					
Post					

In the Vietnam conflict, US forces were stymied by the elaborate tunnel systems built by the North Vietnamese. In the intervening 30 years, not much has changed. Few of the technologies investigated covered any capability for underground sensing. The only reason the platoon category is not black is that the platoon's IR and EO capabilities can be extended to underground system – although sometimes requiring additional light sources.

Ground penetrating radar can be used to look for voids under the surface. The single system discussed in this study is slow and short range. Low light level TV (like night vision glasses) and other IR systems can provide viewing for soldiers in the underground environment.

Significant study is needed to increase the capability of our forces to operate in these regimes.

Chapter 8 – RECOMMENDATIONS FOR FUTURE RESEARCH

It was clear from all of the discussions and study that no single sensor could perform all the functions needed in the urban environment. What is needed is the capability to use multiple sensors on a single platform to improve knowledge of a situation – to combine literal and non-literal information to gain an understanding of a situation.

For example, a vehicle with a short stand-off TTW sensor could also be loaded with a 3D LADAR system to provide high resolution images through windows, a passive IR system to look for hot spots, and a laser vibrometer to look for activity.

Most sensor fusion has focused on networking sensors on disparate platforms. The problem with this scenario is that there is a reliance on communications networks which can be disrupted. It also adds a latency to wait for the information to be relayed through the network to the requester. Furthermore, hosting on the sensors on the same platform allows for feedback between sensors to allow them to cooperate towards achieving a shared understanding of the scene. Having all the appropriate sensors on a single platform improves the flexibility of deployed forces. These sensors can then be augmented by other high-performance sensor platforms in the area over a communications network.

A direct result of needing to integrate multiple sensors on a single platform is size, weight and power. This is most easily seen in the case of a soldier. You'd like a soldier to have all these capabilities but there is no way he could carry a radar, two LADARs, and several passive imaging systems by himself. Intelligent combining of modalities and aggressive miniaturization of the appropriate sensor systems (along with their power supplies) is needed to make multiple-sensor integration possible.

Finally, learning how to exploit orthogonal data sets to gain important new insights will be critical. This integration will be more than simply combining the data from the sensors but using the data from one sensor to feed back to another sensor to improve its data collection. That information will then be used by sensor management functions to support automated detection and identification algorithms – tight cooperation between sensors to solve a particular sensing problem.

Bringing sensors together and finding a way to integrate their information to improve situational awareness, target detection and target identification will greatly improve our ability to bring the fight to the urban landscape.

Chapter 9 – REFERENCES

[1] IST-046/RTG-018, "Results of IST-46 meeting 22-26 March 2004, The Hague", 21 May 2004.

[2] NATO Research and Technology Organisation, "Urban Operations in the Year 2020", RTO-TR-071, France, April 2003.

[3] NATO Research and Technology Organisation, "Land Operations in the Year 2020", RTO-TR-8, France, March 1999.

[4] Baker, C., Radar for Urban Environments, NATO SET-90 Workshop, DCMT, Shrivenham, UK, September 18-21, 2006.

[5] Wicks, M., Waveform Diversity in Intelligent Sensor Systems, IET Forum on Waveform Diversity and Design in Communications, Radar and Sonar, IET Savoy Place, London, UK, November 22, 2006.

Annex A – TECHNOLOGY DESCRIPTION SHEETS

A.1 SUMMARY

The technology description sheets attached here were solicited from the countries involved in the task group and the workshop. They do not represent a comprehensive list of technologies but a sampling. While many are program specific, the workshop attempted to look at them as technologies to evaluate their utility in satisfying urban sensing requirements. Many of them lack the detail one would desire for a good evaluation. These were taken as they were written. Workshop teams either used them as is with whatever interpretation they could make, or rejected them as being insufficient.

Because these technology description sheets were covered in detail earlier in the report, they are only reproduced here without comment for completeness.

A.2 TECHNOLOGY DESCRIPTION SHEETS – MASTER LIST

Number	Title	Submitter
1	Surveillance visualization	Jorgen Ahlberg
2	Acoustic sensor network	Jorgen Ahlberg
3	Combined millimeter/optical surveillance system	Jan Kjellgren
4	Hyperspectral imager in visual/near-infrared	Jorgen Ahlberg
5	Free space optical communication	Dietmar Letalick
6	Optical sight detector	Dietmar Letalick
7	Portable low cost radar sensor for imaging and communication	Johan Rasmusson
8	Hyperspectral VNIR/SWIR/LWIR: Scopes/Binocular, surveillance, sniper detection	Willson
9	Multi/hyperspectral thermal imager	Jorgen Ahlberg
10	Radar	Dan Axelsson
11	Long Wavelength Infrared	Micheal Bentley
12	Coherent radar through wall system	Jan Kjellgren
13	Thermal Surveillance with advanced functionality	Lars Bohman
14	Sensor system for vehicle situation awareness	Lars Bohman
15	Tunable THz imager	Lars Bohman
16	Mono and bistatic low frequency SAR for situation awareness	Lars Ulander and Johan Rasmusson
17	CALADIOM	Eric Stiee and Morgan Brishoual
18	DAOTE	Morgan Brishoual and Patrice Ropars

Number	Title	Submitter
19	PILAR MKII w: Acoustic sniper detection	Morgan Brishoual and Beatrice Coudert
20	CLEO	Morgan Brishoual
21	COBRA	Morgan Brishoual
22	CUIRACE	Morgan Brishoual
23	DEMISTER	Morgan Brishoual
24	Active Imaging System	Vincent Larochelle
25	Airborne Laser Scanner	Ulf Soderman
26	NIR Infrared Sensor (NIR)	Micheal Bentley
27	Hyperspectral imagery (visible and infrared)	Tracy Smithson
28	EO imagery (visible)	James Cruickshank
29	Image Sensor Fusion for Soldier-Borne Applications	Micheal Bentley
30	Midwavelength Infrared Sensors (MWIR)	Micheal Bentley
31	Compact Atmospheric Sounding Interferometer (CATSI)	Hugo Lavoie and Jean-Marc Thériault
32	Short Wave Infrared (SWIR) Sensors	Micheal Bentley
33	Active Millimeter Wave Sensor	Yves de Villers
34	Passive Real-time MMW Imager	Yves de Villers
35	UWB Through-wall radar	Sylvain Gauthier
36	Volumetric Sensor for Mobile Robotics in Complex Terrain	Benoît Ricard
37	Surveillance of Bio-aerosols in large indoor and semi-enclosed outdoor spaces	Jean-Robert Simard
38	Spybowl Felin's optronic ball	Morgan Brishoual
39	Ground Penetrating Radar	Johan Rasmusson
40	Multi-Sensor Chain for Broader Surveillance	Jan Kjellgren
41	Combined Millimeter/optical standoff checkpoint system	Jan Kjellgren
42	Active Defence Sensor System	Jan Kjellgren
43	3D Ladar for UAV or Ground Vehicle	Dietmar Letalick

A.2.1 Requirements

Mapping

Number	Title	Submitter
7	Portable low cost radar sensor for imaging and communication	Johan Rasmusson
9	Multi/hyperspectral thermal imager	Jorgen Ahlberg
11	Long Wavelength Infrared	Micheal Bentley
13	Thermal Surveillance with advanced functionality	Lars Bohman
16	Mono and bistatic low frequency SAR for situation awareness	Lars Ulander and Johan Rasmusson
25	Airborne Laser Scanner	Ulf Soderman
27	Hyperspectral imagery (visible and infrared)	Tracy Smithson
30	Midwavelength Infrared Sensors (MWIR)	Micheal Bentley

Battalion/Air Platforms – Detect, Classify and ID

Number	Title	Submitter
1	Surveillance visualization	Jorgen Ahlberg
4	Hyperspectral imager in visual/near-infrared	Jorgen Ahlberg
5	Free space optical communication	Dietmar Letalick
6	Optical sight detector	Dietmar Letalick
7	Portable low cost radar sensor for imaging and communication	Johan Rasmusson
9	Multi/hyperspectral thermal imager	Jorgen Ahlberg
13	Thermal Surveillance with advanced functionality	Lars Bohman
16	Mono and bistatic low frequency SAR for situation awareness	Lars Ulander and Johan Rasmusson
22	CUIRACE	Morgan Brishoual
24	Active Imaging System	Vincent Larochelle
25	Airborne Laser Scanner	Ulf Soderman
26	NIR Infrared Sensor (NIR)	Micheal Bentley
27	Hyperspectral imagery (visible and infrared)	Tracy Smithson
28	EO imagery (visible)	James Cruickshank
29	Image Sensor Fusion for Soldier-Borne Applications	Micheal Bentley
30	Midwavelength Infrared Sensors (MWIR)	Micheal Bentley
31	Compact Atmospheric Sounding Interferometer (CATSI)	Hugo Lavoie and Jean-Marc Thériault
32	Short Wave Infrared (SWIR) Sensors	Micheal Bentley

Platoon – Detect, Classify and Identify

Number	Title	Submitter
3	Combined millimeter/optical surveillance system	Jan Kjellgren
4	Hyperspectral imager in visual/near-infrared	Jorgen Ahlberg
5	Free space optical communication	Dietmar Letalick
6	Optical sight detector	Dietmar Letalick
7	Portable low cost radar sensor for imaging and communication	Johan Rasmusson
8	Hyperspectral VNIR/SWIR/LWIR: Scopes/Binocular, surveillance, sniper detection	Willson
9	Multi/hyperspectral thermal imager	Jorgen Ahlberg
11	Long Wavelength Infrared	Micheal Bentley
14	Sensor system for vehicle situation awareness	Lars Bohman
15	Tunable THz imager	Lars Bohman
17	CALADIOM	Eric Stiee and Morgan Brishoual
18	DAOTE	Morgan Brishoual and Patrice Ropars
19	PILAR MKII w: Acoustic sniper detection	Morgan Brishoual and Beatrice Coudert
23	DEMISTER	Morgan Brishoual
24	Active Imaging System	Vincent Larochelle
26	NIR Infrared Sensor (NIR)	Micheal Bentley
28	EO imagery (visible)	James Cruickshank
29	Image Sensor Fusion for Soldier-Borne Applications	Micheal Bentley
30	Midwavelength Infrared Sensors (MWIR)	Micheal Bentley
31	Compact Atmospheric Sounding Interferometer (CATSI)	Hugo Lavoie and Jean-Marc Thériault
32	Short Wave Infrared (SWIR) Sensors	Micheal Bentley

Battalion/Air Platforms, Detect and Track

Number	Title	Submitter
2	Acoustic sensor network	Jorgen Ahlberg
21	COBRA (counter battery radar)	Morgan Brishoual
22	CUIRACE	Morgan Brishoual

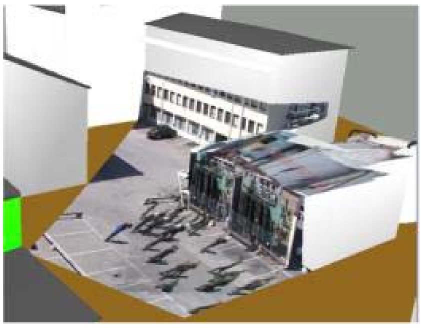
Platoon, Detect and Track

Number	Title	Submitter
7	Portable low cost radar sensor for imaging and communication	Johan Rasmusson
8	Hyperspectral VNIR/SWIR/LWIR: Scopes/Binocular, surveillance, sniper detection	Willson
10	Radar	Dan Axelsson
11	Long Wavelength Infrared	Micheal Bentley
12	Coherent radar through wall system	Jan Kjellgren
14	Sensor system for vehicle situation awareness	Lars Bohman
15	Tunable THz imager	Lars Bohman
17	CALADIOM	Eric Stiee and Morgan Brishoual
18	DAOTE	Morgan Brishoual and Patrice Ropars
19	PILAR MKII w: Acoustic sniper detection	Morgan Brishoual and Beatrice Coudert
20	CLEO	Morgan Brishoual

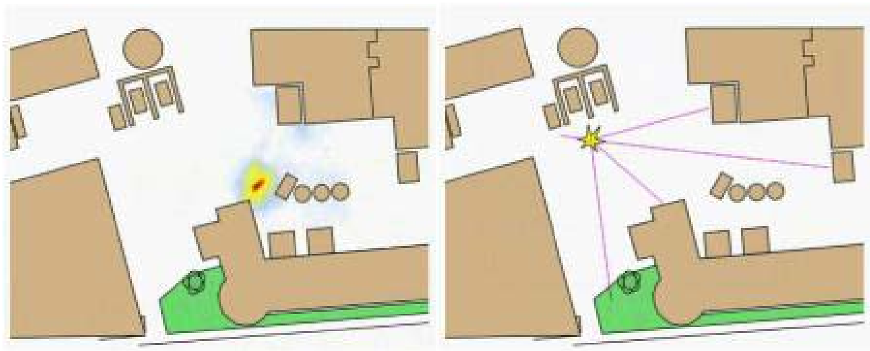
A.3 TECHNOLOGY DESCRIPTION SHEETS

A complete set of technology description sheets follows.

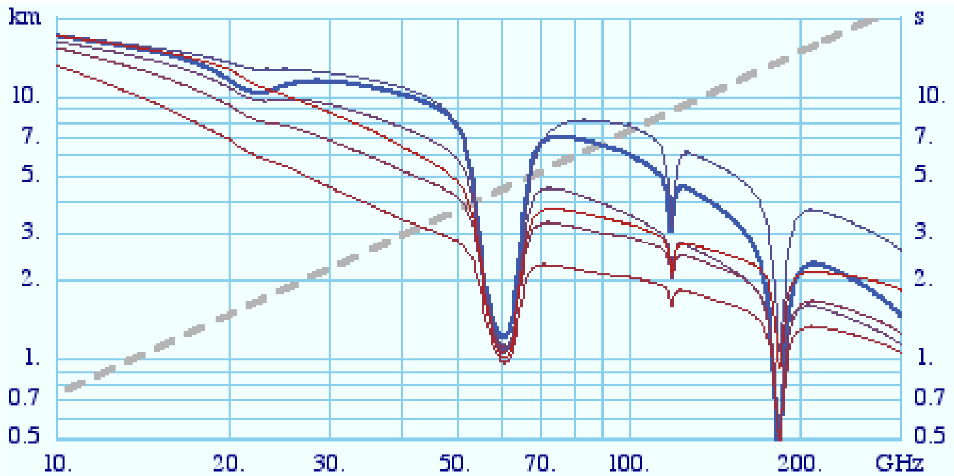
NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="2">Surveillance Visualization</td><td colspan="2">Concept Number: 1</td></tr>
<tr><td colspan="5">Primary Sensing Requirements: 9. Other Sensing
Secondary Sensing Requirements: 4. Identification, 5. Classification, 6. Detection, 8. Tracking
Information Requirements: 5. RT Surveillance of Objectives, 7. Culture and Social Visualization, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
Staring EO cameras (thermal or visual). Imagery (video) is projected onto a 3D model of the surveyed area, multiple camera views visualized simultaneously. Improves situation awareness.</td><td colspan="3">Illustration
</td></tr>
<tr><td>General System Description</td><td colspan="4">Surveillance (CCTV) operators are presented a 3D model with surveillance video projected onto the model.</td></tr>
<tr><td>System Performance</td><td colspan="4">Scaleable.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
<1</td><td>Volume
1 dm^3 per unit</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)
<1 per unit</td></tr>
<tr><td>Mobile/Stationary
Both</td><td>Platform Type
Vehicle/Soldier/Fixed</td><td>Data Rate
Variable</td><td>Maturity (TRL)
6</td></tr>
<tr><td>CONOPS</td><td colspan="4">Fixed system installed in advance in area to be surveyed. Images streamed to client equipped with 3D-model. Visualization of multiple sensors on computer screen.</td></tr>
<tr><td>Limitations</td><td colspan="4">Requires 3D model. Requires exact positioning of cameras (which is simpler for stationary cameras than for cameras mounted on UGV/UAV/soldier).</td></tr>
<tr><td>Communications</td><td colspan="4">High bandwidth is required to stream high quality imagery from sensors.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4">Automatic sensor positioning. 3D model building.</td></tr>
<tr><td>Author</td><td colspan="4">Dr. Jörgen Ahlberg, Division of Sensor Technology, Swedish Defence Research Agency.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">Acoustic Sensor Network</td><td>Concept Number: 2</td></tr>
<tr><td colspan="5">Primary Sensing Requirements: 5. Classification, 6. Detection, 8. Tracking
Secondary Sensing Requirements: –
Information Requirements: 1. Blue Force Tracking, 3. Red Force Tracking, 5. RT Surveillance of Objectives, 7. Culture and Social Visualization, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
A network of acoustic sensors that classifies and localizes sound sources.</td><td colspan="3">Illustration
</td></tr>
<tr><td>General System Description</td><td colspan="4">Stationary sensors for surveillance.</td></tr>
<tr><td>System Performance</td><td colspan="4">Ability of pinpoint temporary signals like gunshot with resolution depending on access to direct or reflected acoustical waves. The sensing range is depending on the geometry and separation of the buildings. (50m-1km).</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
0.1</td><td>Volume
Cell phone size</td><td>Power Requirement
Batteries</td><td>Estimated Cost ($ 1000)
Single sensor unit from 5 and up</td></tr>
<tr><td>Mobile/Stationary
Stationary</td><td>Platform Type
Fixed</td><td>Data Rate
100kbit/s per unit</td><td>Maturity (TRL)
1-5</td></tr>
<tr><td>CONOPS</td><td colspan="4">Used for surveillance of an area. Detects, classifies and tracks sound sources as vehicles, groups of people (left illustration) or gunfire (right illustration).</td></tr>
<tr><td>Limitations</td><td colspan="4">Requires exact positioning of sensors. Requires power and network to each node.</td></tr>
<tr><td>Communications</td><td colspan="4">Radio communication to a central node for network processing and presentation to end user.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4">Noise reduction, separation of different sound sources.</td></tr>
<tr><td>Author</td><td colspan="4">Jörgen Ahlberg, Hans Habberstad, Division of Sensor Technology, Swedish Defence Research Agency.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">Combined Millimeter/Optical Surveillance System</td><td>Concept Number: 3</td></tr>
<tr><td colspan="5">Sensing Requirements</td></tr>
<tr><td colspan="5">Primary Sensing Requirements 4. Identification, 5. Classification, 6. Detection, 8. Tracking
Secondary Sensing Requirements: –
Information Requirements: 3. Red Force Tracking, 9. Foe Discrimination, 14. Identification of People and Equipment in Real-Time</td></tr>
<tr><td colspan="2">Technology Description</td><td colspan="3"></td></tr>
<tr><td colspan="2">Coherent radar methods employed at high millimeter frequencies for the detection and localization of especially moving targets. Optical system senses the natural reflections in the visual band or the natural reflections and emissions in the ir-region.
The figure shows the radar range as a function of frequency for atmospheric conditions corresponding to summer, winter, fog, rain 4 mm/h, rain 10 mm/h and snow are indicated with colors from blue to red in corresponding order. The gray dotted line indicates the update time for a single receiver when searching a solid angle corresponding to the cone angle 16˚.</td><td colspan="3">
</td></tr>
<tr><td>General System Description</td><td colspan="4">The system consists of a coherent millimeter wave pulse-doppler multiple channel radar operating at 220 GHz combined with a passive optical system. The radar has multiple receivers and a scanning antenna to achieve the required solid angle coverage. For classification applications the optical system will be operated in a high-resolution mode guided by the radar.</td></tr>
<tr><td>System Performance</td><td colspan="4">The radar operational range against military personnel and vehicles is supposed to be about 1 km. Cross range resolution is about 3 m at 1 k m. The optical system is designed for classification of personnel at 1 km (angle resolution ≈ 0.05 mrad or Δx ≈ 5 cm at 1 km). The radar has a field of view of corresponding to a cone angle of 16˚ and an update rate about 1 Hz.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
50-100 kg</td><td>Volume
100-500 dm^3</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)
20-100(Large series)</td></tr>
<tr><td>Mobile/Stationary
Stationary</td><td>Platform Type
Tripod or vehicle</td><td>Data Rate
1 Hz</td><td>Maturity (TRL)
2</td></tr>
<tr><td>CONOPS</td><td colspan="4">The system is applicable for surveillance of people in limited areas in and outdoors within a range of about 1 km. It will facilitate limited area surveillance and the guarding of crowds where civilians and foes are mixed.</td></tr>
</table>

Limitations	*In operation the system must be static. The radar cross-range resolution limits the operational range. For operation at even higher frequencies, between 500-1000 GHz, also the atmosphere will limit the range. Precipitation and fog will limit the operation of optical systems.*
Communications	*How to communicate with the sensor.*
Critical Technologies	*The most critical components or subsystems limiting the performance of millimeter wave systems are sources, detectors and antenna system. At present there are ongoing research efforts to develop systems at 220 GHz. Moving system is in principle possible but will be much more complicated and more research regarding antenna system and signal processing is required.*
Author	*Jan Kjellgren, FOI, Dep. of Sensor Technology, Linköping, Sweden.*

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Hyperspectral Imager in Visual/Near-Infrared*	Concept Number: 4

Primary Sensing Requirements: *1. Mapping Facilities, 2. Mapping Route, 3. Mapping Utilities, 5. Classification, 6. Detection*

Secondary Sensing Requirements: *8. Tracking*

Information Requirements*: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 8. Buildings Layouts, 9. Foe Discrimination, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports*

Technology Description

Hyperspectral VNIR sensors sample the incoming radiation in many bands within the visual and near infrared domains (reflected radiation).

Illustration

General System Description	*Mounted on UAV/UGV. Present systems scanning.*			
System Performance	*Scanning, ~1000 pixels per scanline, 200 spectral bands.*			
System Specifications	***Weight (kg)*** *1*	***Volume*** *3 dm^3*	***Power Requirement***	***Estimated Cost ($ 1000)*** *40*
	Mobile/Stationary *Mobile*	***Platform Type*** *UAV/UGV*	***Data Rate***	***Maturity (TRL)*** *Sensor TRL =8. System TRL = 5*
CONOPS	*Used on UAV/UGV for mapping, recon, surveillance, ATD/R. Since each pixel contains material information, ATD/R can be implemented on pixel basis (see illustration).*			
Limitations	*Transmission of imagery requires high power and bandwidth. Processing for ATD/R must possibly be done on the device (before transmission). Requires daylight.*			
Communications	*High bandwidth is required to stream imagery from hyperspectral sensors.*			
Critical Technologies	*Image processing methods for real time processing.*			
Author	*Dr. Jörgen Ahlberg, Division of Sensor Technology, Swedish Defence Research Agency.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Free Space Optical Communication*			Concept Number: 5
Primary Sensing Requirements:				
Secondary Sensing Requirements:				
***Information Requirements**: 15. Graphic and Verbal Situation Reports*				
Technology Description *Free space optical communication based on same technology as fiber optic communication, but in free space. The eye-safe wavelength 1.55 µm has good atmospheric transmission.*	***Illustration***  *(Thermotrex Corp.)*			
General System Description	*High bandwidth enables high performance links for video etc. Can be combined with optical tags and quantum key distribution. Systems can be integrated with existing E/O systems (sights, range finders, warning systems). Particularly intended for point-to-point communication. 5×3×1 cm for a handheld device. Larger devices for platform use. Design depends on application, required range performance and bandwidth, etc.*			
System Performance	*High bandwidth, up to 10 Gbit/s. Jamming resistant. Difficult to tap.*			
System Specifications	***Weight (kg)*** *3-50 kg*	***Volume*** *1-30 l*	***Power Requirement***	***Estimated Cost ($ 1000)*** *From 5 and up*
	Mobile/Stationary *Mobile*	***Platform Type*** *Handheld or any platform*	***Data Rate*** *10 Gbit/s*	***Maturity (TRL)*** *TRL = 9 for free LOS systems. TRL = 5 for non-LOS systems.*
CONOPS	*1) Quiet and fast communication between moving vehicles (helicopters, ground vehicles, etc.).* *2) Fast communication in ground sensor networks.* *3) Quiet and fast link between ground and air vehicles (UAVs).* *4) Communication in urban terrain (indoors, in tunnels).*			
Limitations	*Weather dependant. Direct link requires free line-of-sight (LOS). Very narrow lobes require process to establish contact. (New technology using UV wavelengths and atmospheric scattering enables communication without free LOS.)*			
Communications				
Critical Technologies	*UV lasers (for non-LOS applications).*			
Author	*Dr. Dietmar Letalick, FOI (Swedish Defence Research Agency), Division of Sensor Technology.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Optical Sight Detector*			Concept Number: 6
Primary Sensing Requirements: *6. Detection* ***Secondary Sensing Requirements:*** *5. Classification* ***Information Requirements****: 3. Red Force Tracking, 5. RT Surveillance of Objectives, 10. Prediction of Adversary Actions, 14. Identification of People and Equipment in Real-Time*				
Technology Description *Detection and localization of retro-reflected optical radiation from optical sights.*		***Illustration*** 		
General System Description	*Illuminating laser pulses are transmitted in the direction of the area to be interrogated. The reflection from optical sights etc. is used to detect and locate the objects. With short transmitted pulses, the specific construction of the optics can be characterized, enabling classification of the threat. Sensor head is mounted on a tripod; control unit may be located elsewhere.*			
System Performance	*Detection range: Several km. Positioning accuracy: angular: µrad, range 1 m.*			
System Specifications	***Weight (kg)*** *5-10 kg*	***Volume*** *Shoe box*	***Power Requirement*** *300 W*	***Estimated Cost ($ 1000)*** *From 10 and up*
	Mobile/Stationary *Mobile*	***Platform Type*** *Tripod*	***Data Rate***	***Maturity (TRL)*** *9*
CONOPS	*Optical sights and other optical sensors can be detected and localized. Can be used to scan for snipers.*			
Limitations	*The illuminating laser and receiver needs to cover the whole spectral range of interest (may require several lasers/detectors).*			
Communications	*Video image of the scene of interest can be transmitted, but is not required. Indications of targets can be made in a single video frame.*			
Critical Technologies				
Author	*Dr. Dietmar Letalick, FOI (Swedish Defence Research Agency), Division of Sensor Technology.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Portable Low Cost Radar Sensor for Imaging and Communication*	Concept Number: 7

Primary Sensing Requirements: *1. Mapping Facilities, 6. Detection, 8. Tracking*

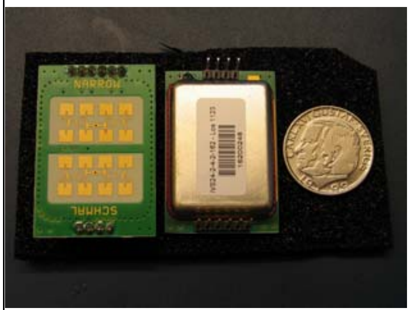
Secondary Sensing Requirements: *4. Identification, 5. Classification*

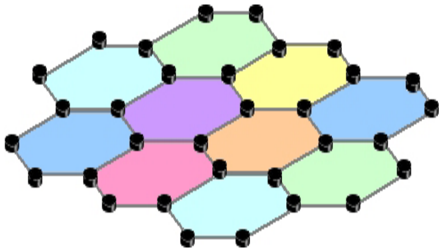
Information Requirements*: 5. RT Surveillance of Objectives, 6. Communications Buildings Layouts, 11. Sites which may be Centers of Gravity, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports*

Technology Description

High resolution streaming radar images in Doppler and range can be reached using FMCW (Frequency Modulated Continuous Wave) radars or pulsed ultrawide band (UWB) radar systems with very short pulses (ns). FMCW and UWB are two cost effective and well established radar technologies with potentially low energy consumption and small size.

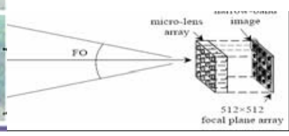
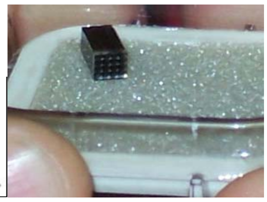
Illustration





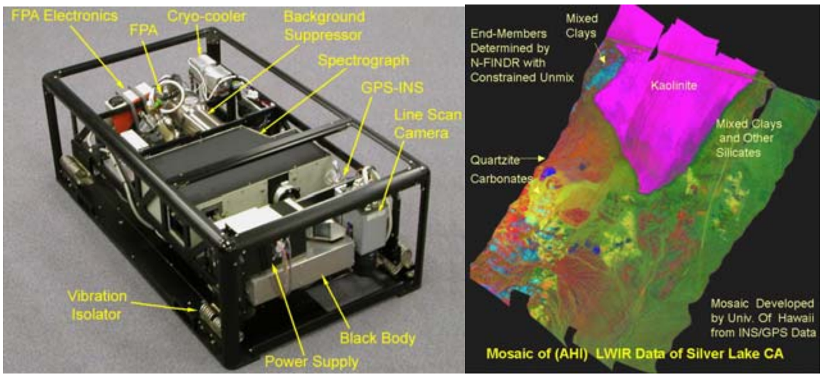
General System Description	*Clever line, surface or volume surveillance using communicating radar sensors in a network Used manually or on any platforms for situation awareness, mapping and communication.*			
System Performance	*Volumes 100 m x 100 m x 100 m can be monitored.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	0.5 kg	*0.1 m x 0.1 x 0.1 m*	*10 W*	*1*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Mobile	*Any, personal device*	*Application dependent*	*3-6*
CONOPS	*Open and concealed targets can be detected and classified. Internal structure of buildings can be mapped. Secure communication and positioning can be made in difficult urban environments.*			
Limitations	*Sufficiently low frequencies must be used for good penetration.* *Antenna technology for low frequency antennas with large bandwidth and small size.*			
Communications	*Real time display with streaming images. A datalink for communication can be included in the concept.*			
Critical Technologies	*Microwave circuits. Small antennas. Low power and low weight radar electronic.*			
Author	*Johan Rasmusson and Lars Ulander, Dept. of Sensor Technology, FOI, Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Hyperspectral VNIR/SWIR/LWIR: Scopes/Binocular, Surveillance, Sniper Detection*			Concept Number: 8
Sensing Requirements				
Primary Sensing Requirements: 4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Alert sensor ***Secondary Sensing Requirements:*** ***Information Requirements:*** *5. RT Surveillance of Objectives, 6. Communications, 11. Sites which may be Centers of Gravity*				
Technology Description	***Illustration***			
Visible-Near InfraRed (VNIR) and Long Wave IR (LWIR) HyperSpectral (HS) non-scanning imagers for scopes and binoculars isolate targets from background, displaying results at 20 images/second.	    			
General System Description	*VNIR/HS made from microlens array and narrow band filters and commercial CCD array with custom ASIC processor acquires/analyzes/displays processed image. LWIR/HS microbolometer array of unique design acquires all narrow band spectral elements of all spatial pixels simultaneously.*			
System Performance	*Detection of targets of many targets of interest. Field of view: lens dependent.* *Response time: 50 milli-second appropriate for scopes and binocular implementation.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
		Currently 4" x 4" x 4" *Near future systems ½" x ½" x 2"*	*< 5 watt operation*	*50* *In quantity 2-3*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Portable			*Prototype Q2 06, 1st products Q4 06 small devicesQ2 07*
CONOPS	*This device could be used for any place scopes and cameras are used today.*			
Limitations	*VNIR limited to daylight or artificial lighting. Objects hidden behind solid obstacles cannot be seen. Meant to aid the warrior in finding targets, not to automatically determine the targets.*			
Critical Technologies	*Custom proprietary detector components, small devices require custom microprocessor (ASIC) in multi-chip module.*			
Author	*Willson, US Army RDECOM/ARDEC.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Multi/Hyperspectral Thermal Imager*		Concept Number: 9	
Primary Sensing Requirements: *1. Mapping Facilities, 2. Mapping Route, 3. Mapping Utilities, 5. Classification, 6. Detection* ***Secondary Sensing Requirements:*** *8. Tracking* ***Information Requirements****: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 8. Buildings Layouts, 9. Foe Discrimination, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports*				
Technology Description *Multispectral thermal sensors sense emitted energy from objects in several bands within the MWIR and/or LWIR domain.*	***Illustration***			
General System Description	*Mounted on UAV/UGV. Present systems scanning (hyperspectral) or staring (multispectral).*			
System Performance	*Scanning hyperspectral systems: 256 pixels per scanline.* *Staring multispectral systems: VGA resolution.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	5-150	*10-500* dm^3	*1000 W*	*400*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Mobile	*UAV/UGV*	*~20 MB/s*	*5*
CONOPS	*Used on UAV/UGV for mapping, recon, surveillance, ID, detection, and mobility. With enough spectral bands available, each pixel contains material information and ATD/R can be implemented on pixel basis. Useful in low/no light situations for detection/recognition, to see through common battlefield obscurants.*			
Limitations	*Transmission of imagery requires high power and bandwidth. Processing for ATD/R must possibly be done on the device (before transmission).*			
Communications	*High bandwidth is required to stream imagery from sensors (~20 MB/s for hyperspectral sensors).*			
Critical Technologies	*Image processing methods for real time processing.*			
Author	*Dr. Jörgen Ahlberg, Division of Sensor Technology, Swedish Defence Research Agency.*			



Images of the AHI sensor from the University of Hawaii (www.higp.hawaii.edu/ahi)

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Miniradar – Handheld Doppler Radar for TWS*			Concept Number: 10
Primary Sensing Requirements: *6. Detection, 9. Other Sensing* ***Secondary Sensing Requirements:*** *5. Classification* ***Information Requirements****: 5. <RT Surveillance of Objectives>, 14. <Identification of People and Equipment in Real-Time>*				
Technology Description *Doppler radar 10 GHz.*		***Illustration***  		
General System Description	*Miniradar is a personal, handheld, battery operated device. Typically, it is used by holding it against a wall for a couple of seconds and if something moves on other side the operator will get a visible and/or audible alarm.*			
System Performance	*Very sensitive to motions, may detect a movement of mm for a human, i.e. breathing. It is possible to detect moving objects 5-10 meters behind a 20 cm thick concrete wall. The false alarm rate is extremely low.*			
System Specifications	***Weight (kg)*** *0,225*	***Volume*** *10x15x2.5 cm*	***Power Requirement*** *Batteries*	***Estimated Cost ($ 1000)*** *< 1*
	Mobile/Stationary *Mobile*	***Platform Type*** *Handheld*	***Data Rate***	***Maturity (TRL)*** *7*
CONOPS	*Used by soldiers or guards for targeting, mapping, recon, surveillance, detection, and mobility. See through walls and obstacles. Invisible surveillance. Useful in all weather conditions. May 'see' round corners due to reflections.*			
Limitations	*Low resolution (The covered area is quite big and there is no information about where within this area the target is). Cannot see through metal plates. May be difficult to decide what area and distance is covered due reflections and to the lack of distance-to-target information.*			
Communications	*Future development incorporates communication link to main unit.*			
Critical Technologies	–			
Author	*Dan Axelsson, Swedish Defence Research Agency (FOI) Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Long Wavelength Infrared (LWIR)*	Concept Number: 11

Information Requirements

Primary Sensing Requirements: *4. Identification, 5. Classification, 6. Detection, 8. Tracking*

Secondary Sensing Requirements: *1. Mapping Facilities, 2. Mapping Route*

Information Requirements*: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 8. Buildings Layouts, 14. Identification of People and Equipment in Real-Time*

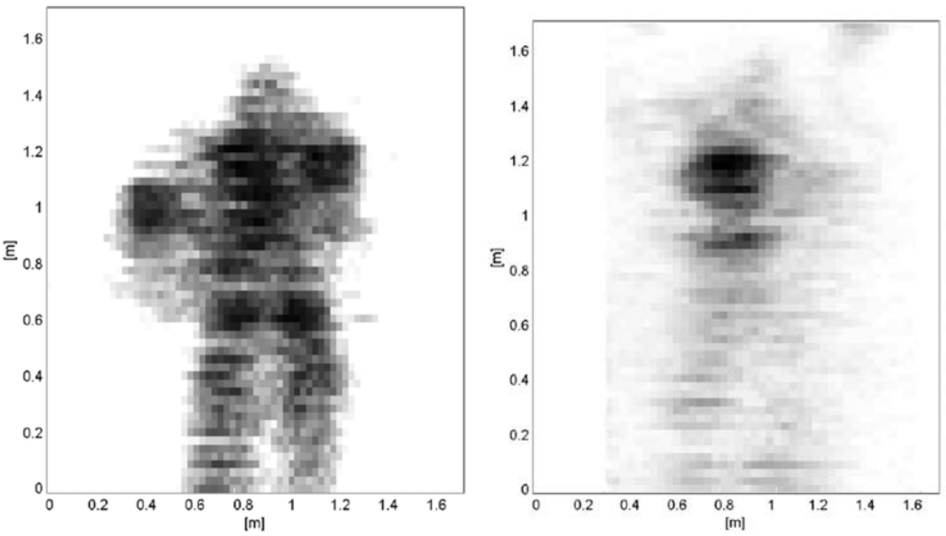
Technology Description

Long Wave IR sensors sense emitted energy from objects in the 8-12 micron waveband.

Illustration

General System Description	*Used in weapon sights or mounted on small UAV/UGV. Some application for helmet mounted mobility sensors. Low resolution versions can be used in UGS.*			
System Performance	*Resolutions of 160x120 up to 640x480. Lower power than currently fielded systems. Fields of view from 18-40 degrees with current resolutions, both weapons mounted and helmet mounted.*			
System Specifications	***Weight (kg)***	***Volume*** *2" x 4" x 3"*	***Power Requirement***	***Estimated Cost ($ 1000)*** *10 and up*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)*** *9+*
CONOPS	*Used on UAV/UGV for mapping, recon, surveillance, ID, detection, and mobility. Used by soldiers on weapon or helmet for mobility, targeting, mapping, recon, surveillance, ID, detection, and mobility. Useful in low/no light situations for detection/recognition, to see through common battlefield obscurants.*			
Limitations	*Not compatible with current issue aiming devices, low resolution, cannot see through glass, low scene contrast at thermal crossover (dawn/dusk timeframes). Transmission of imagery requires high power consumption.*			
Critical Technologies	*Uncooled Focal Plane Arrays in higher resolution than 640x480. Low power electronics, common power source.*			
Author	*Micheal Bentley, US Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) USA.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Coherent Radar Through Wall System*			Concept Number: 12
Primary Sensing Requirements: *1. Mapping Facilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking* ***Secondary Sensing Requirements:*** *–* ***Information Requirements****: 3. Red Force Tracking, 8. Buildings Layouts*				
Technology Description *The dielectric properties of different wall materials allow electromagnetic waves at microwave frequencies to propagate through walls. The propagated field is attenuated depending on type of material and frequency. Coherent techniques facilitate the detection of very week signals from a moving target.* *[1] A. Jänis, S. Nilsson, L.-G. Huss, M. Gustafsson, and A. Sume, "Through-the wall imaging measurements and experimental characterization of wall materials," presented at Military Remote Sensing, London, UK, 2004.*	 *The figure shows radar images from incoherent measurements through two different types of walls at 94 GHz: two 1.5 cm thick plasterboard separated by a 5 cm air slit (left image); a 1.5 cm thick chipboard (right image). The radar is located 5 m from the wall at test and the target person is located on the other side 15 m from the wall, compare [1]*			
General System Description	*The system consists of coherent mono-pulse radar operating in a part of the frequency interval 5-90 GHz. The radar has multiple receivers for direction estimation and resolving the reflections in the dimensions of range and doppler.*			
System Performance	*The radar range is estimated to about 30 m indoors and the doppler resolution designed to detect slowly moving people or parts of peoples (breathing and heart beating).*			
System Specifications	***Weight (kg)*** *10-20*	***Volume*** *10-50 dm*^{3}	***Power Requirement***	***Estimated Cost ($ 1000)*** *1-10*
	Mobile/Stationary *Stationary operation*	***Platform Type*** *Tripod or mounted on a wall*	***Data Rate***	***Maturity (TRL)*** *4 – 8 depending on system complexity*
CONOPS	*The system is applicable for detection and location of moving people behind walls in and outdoors.*			
Limitations	*In operation the system must be static. The performance will be limited to short ranges due to complex multi-path propagation of the reflected field and due to the attenuation of the field when propagating through the wall material.*			
Communications				

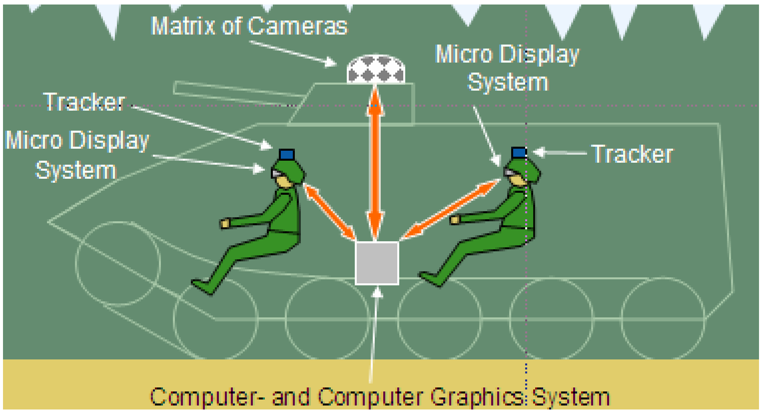
Critical Technologies	*System design and knowledge about indoor propagation and material attenuation for indoor radar applications.*
Author	*Jan Kjellgren, FOI, Dep. of Sensor Technology, Linköping, Sweden.*

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">Thermal Surveillance with Advanced Functionality</td><td>Concept Number: 13</td></tr>
<tr><td colspan="5">Primary Sensing Requirements: 1. Mapping Facilities, 2. Mapping Route, 3. Mapping Facilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Other Sensing
Secondary Sensing Requirements:
Information Requirements: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 9. Foe Discrimination, 14. Identification (of People and) Equipment in Real-Time</td></tr>
<tr><td colspan="3">Technology Description
High performance thermal imager (probably supported by a high resolution EO camera in the visual) in an UAV with a highly improved geo-localization system, i.e. advanced gyros to keep thorough track of sensor pointing and platform movements. On-board advanced signal processing for autonomous reconnaissance. Real time signal processing on the ground. Merging of sensor information and 3D models and maps. MMI with presentation of evaluated and emphasized information in order to facilitate for the operator.</td><td colspan="2">Illustration
</td></tr>
<tr><td>General System Description</td><td colspan="4">The sensor system is incorporated in a small UAV (fixed or rotor winged). The main IR sensor allows day and night capability. Autonomous modes. Link to ground station, which supports the UAV system with supplemented information and mission order and in the other direction transmit images with detections. Different modes to present information for the operator, for instance big stable picture much larger than sensor f.o.v.? (Light weighted sensor system and shrinking volume. Power supply crucial).</td></tr>
<tr><td>System Performance</td><td colspan="4">Coverage of several hundred m^2. Footprint on ground less than 1 cm^2. Key performance parameters are given related to the system and the information requirements. Advanced image/signal processing in 30 Hz rate.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)</td><td>Volume</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)</td></tr>
<tr><td>Mobile/Stationary</td><td>Platform Type</td><td>Data Rate</td><td>Maturity (TRL)
5</td></tr>
<tr><td>CONOPS</td><td colspan="4">Multi-role system. The systems could be sent in for reconnaissance missions or be used to support operations with blue force tracking or track and follow modes for suspected vehicles.</td></tr>
<tr><td>Limitations</td><td colspan="4"></td></tr>
<tr><td>Communications</td><td colspan="4">Ordinary data link with the UAV.</td></tr>
</table>

Critical Technologies	*Methodology, development and implementation of sensor management. TRL 5.* *Software as well as hardware for real time image and signal processing. Available in 5 years. The MMI interface needs further development. 5 years? Robust geo-localisation technique. ID-tags technology for blue force tracking. Low power high performance uncooled staring array detectors in 8-12 µm. TRL2*
Author	*Lars Bohman, Defence Research Agency, Division of Sensor Technology, Sweden.*

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Sensor System for Vehicle Situation Awareness*			Concept Number: 14
Primary Sensing Requirements: *9. Other Sensing* ***Secondary Sensing Requirements:*** ***Information Requirements****: 13. Performance of Capability*				
Technology Description *Staring EO cameras (visual or thermal), a sufficient number to cover the needed area coverage. Images are put in big memory. The operator, supervised concerning body movements and gaze direction, is presented a seamless image with optional augmented information like threat detection within field of sight.* *The system offers a good situation awareness capability within the whole hemisphere.* *Control of situation close around the vehicle as well as potential threats high up on buildings.*	***Illustration***  			
General System Description	*The sensor and display technology is incorporated in an armoured vehicle. The system allows the operator to look in any direction covered by the sensors. Information from the command and control system may be overlaid. System can be used for driving.* *The operator can physically be anywhere in vehicle. System allows more than one person to look "through" the armour. Sensors can also be operated remotely. Simple man carried equipment. The system could be based on low cost commercial components.*			
System Performance	*Fixed mounted sensors imply no delay between operator and sensor. Allows peripheric viewing. High spatial resolution and wide field of sight (360˚).*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)*** *5*
CONOPS	*Vehicle personnel surveillance during any mission (all ROE) in the urban terrain.*			
Limitations	*Principal limitations of the sensor technology or the system. Omit any information which would prohibit the distribution of this worksheet to all NATO and Partner for Peace countries.*			
Communications	*Data communication within the vehicle. Potential for communication with remote observer or remote driver.*			
Critical Technologies	*Close range staring EO sensors. Available today. Display system needs further technology development. TRL 5.Computer maturity (band width is crucial).*			
Author	*Lars Bohman, Swedish Defence Research Agency, Division of Sensor Technology, Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Tunable THz Imager*			Concept Number: 15
Primary Sensing Requirements: *1. Mapping Facilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Other Sensing* ***Secondary Sensing Requirements:*** ***Information Requirements****: 5. RT Surveillance of Objectives, 14. Identification of (People) and Equipment in Real-Time*				
Technology Description *Tunable THz imager. Passive short range imaging array sensor tunable from mm wavelengths to thermal wavelengths.*		***Illustration***		
General System Description	*The sensor technology is incorporated in appropriate systems. The idea is to use high resolution images in IR when possible and switch to mm wavelengths when needed to* ***maintain image*** *capability in dusty conditions which happens after firing in urban environment.*			
System Performance	*Varying image quality.* *Possible sensor performance parameters are not yet available.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)*** *1-2*
CONOPS	*The new sensor may replace thermal imagers in close range applications.*			
Limitations				
Communications				
Critical Technologies	*Detector technology on research level.*			
Author	*Lars Bohman, Swedish Defence Research Agency, Division of Sensor Technology, Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Mono and Bistatic Low Frequency SAR for Situation Awareness*		Concept Number: 16	

Primary Sensing Requirements: *1. Mapping Facilities, 6. Detection*

Secondary Sensing Requirements: *4. Identification, 5. Classification, 8. Tracking*

Information Requirements*: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 5. RT Surveillance of Objectives, 8. Buildings Layouts, 11. Sites which may be Centers of Gravity, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports*

Technology Description

High resolution synthetic aperture radar images can be reached using a large bandwidth and aperture. Low frequency radar has good penetration in vegetation and most building materials. Bistatic configurations can be used to improve the target to clutter ratio.

Illustration

Conventional map and SAR image of an urban area

General System Description	*Used for ground truth mapping and situation awareness over large areas.*			
System Performance	*Areas > 5000 km^2 / h can be mapped within hours. Image resolution down to 0.5m x 0.5 m.*			
System Specifications	***Weight (kg)*** *> 100 kg*	***Volume*** *> 0.5 x 0.5 x 0.5 m excluding antennas.*	***Power Requirement*** *> 1 kW*	***Estimated Cost ($ 1000)*** *> 100*
	Mobile/Stationary *Mobile*	***Platform Type*** *Airborne*	***Data Rate*** *Application and resolution dependent*	***Maturity (TRL)*** *Monostatic system: 9* *Bistatic systems .3-6*
CONOPS	*Maps based on SAR data can be generated. Open and concealed targets can be detected. Ground moving target indication. Bistatic clutter suppression. Internal structure of buildings can be mapped.*			
Limitations	*Sufficiently low frequencies must be used (< 1 GHz) for good penetration.* *Bistatic and multistatic configurations require separated receiving and transmitting platforms.*			
Communications	*Postprocessing. A datalink with high bandwidth is required to stream realtime SAR images.*			
Critical Technologies	*Small antennas. Low power and low weight radar electronics required for small UAVs.*			
Author	*Lars Ulander and Johan Rasmusson, Dept. of Sensor Technology, FOI, Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	***CALADIOM*** *(Capteur A Longue Autonomie pour la Détection et l'Identification d'Objectifs Mobiles)* *Unattended Ground Alert Sensor*	Concept Number: 17

Information Requirements

Primary Sensing Requirements: *4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Alert Sensor*

Secondary Sensing Requirements:

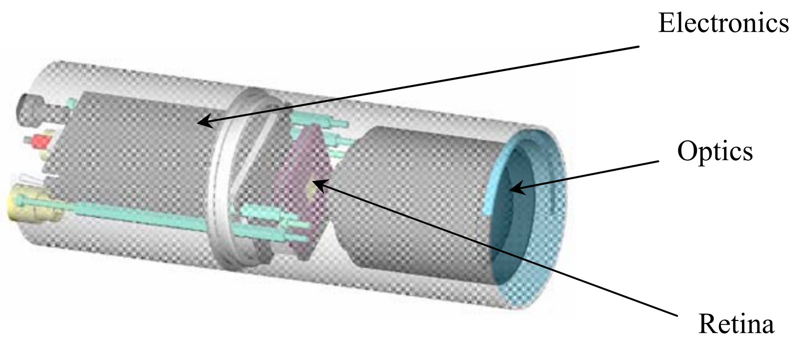
Information Requirements*: 11. Sites which may be Centers of Gravity*

Technology Description

The used technology is a Programmable Artificial Retina (PAR). The PAR is a focal plan array detector (200x200 pixels) where the ANC (analogic-numeric conversion) of the signal, is integrated in the pixel near the photosensitive area.

For this time, the sensor is based on a ***Visible*** *CMOS PAR. The on-going feasibility study should be able to aim an* ***Infrared*** *retina based on an uncooled microbolometer detector.*

Illustration



General System Description	*The sensor technology is incorporated in a system that could be used in urban operations. Its function is to survey, to analyze the scene and to wake up another high performance sensor (IR camera, radar, …) for identification of mobile targets.*
System Performance	*The attended detection range of such a sensor is 1000 m.* *The night survey will be made with the Infrared version.*

System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	1,6 kg	*1,5 liter*	*1,5 W*	*Not significant*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
				6

CONOPS	*In an urban operation, CALADIOM can survey an area continually during several days or weeks. In addition, the sensor integrates some detection and tracking processing that permit to wake up an other high performance sensor via a link, when a potential target is detected.* *The retina technology could be used for the robots, the UAVs, …*
Limitations	*The Visible PAR can't be used in the night. Infrared PAR is needed.* *The system is useless with a smokes and obscurants presence.*
Critical Technologies	*Infrared PAR, Technology transition year 2009.*

Author	*Eric STIEE, DGA/SPART (France), French MoD/Land armament program department, Technical procurement executive, optronic and counter surveillance.* *Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.*

NATO SET-076/TG-44 Technology Concept Description

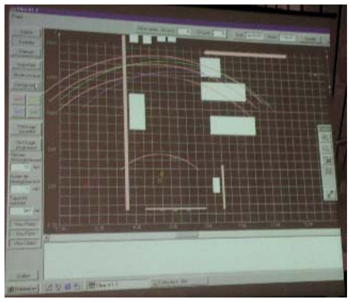
<table>
<tr><td>Sensor Technology</td><td colspan="2">DAOTE : Acoustic-Optronics Device to Detect Hiding Sniper</td><td colspan="2">Concept Number: 18</td></tr>
<tr><td colspan="5">Information Requirements
Primary Sensing Requirements: 5. Classification, 6. Detection (waves, optical sights), 8. Tracking (bullet trajectory, real time), 9. Anti-sniping
Secondary Sensing Requirements: 1. Mapping Facilities, 2. Mapping Route
Information Requirements: 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
This device could be used following different configurations in urban operation : anti-sniping, building and people protection. Following the tactical and technical procedure put in place by the sniper, his localization could be detected :
• Before sniper firing : sniper detection and gunner sight detection (optical hostile sights).
• After sniper firing : ammunition trajectory detection (or atmospheric perturbations created by ammunition) and residue firing detection.</td><td colspan="3">Illustration
</td></tr>
<tr><td>General System Description</td><td colspan="4">DAOTE is principally composed of optronic and acoustic systems with an integrated display (remote display).
Optronic part : 1 day camera with multi field of view, 1 pointed optics system, 1 laser rangefinder, 1 laser pointer to designate the target and electrical interfaces.
Acoustic part : 3 acoustic antennas on tripod and 1 display module.</td></tr>
<tr><td>System Performance</td><td colspan="4"></td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)</td><td>Volume</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)
Several thousand US dollars</td></tr>
<tr><td>Mobile/Stationary</td><td>Platform Type</td><td>Data Rate</td><td>Maturity (TRL)
7</td></tr>
<tr><td>CONOPS</td><td colspan="4">This device could be used following different configurations in urban operation : anti-sniping, building and people protection.</td></tr>
<tr><td>Limitations</td><td colspan="4">Meteorological situation end environment can alter significantly acoustic performances (buildings, vegetation).</td></tr>
</table>

Critical Technologies	
Author	*Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.* *Patrice ROPARS, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, robotic and zone surveillance.*

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">PILAR MKII.w: Acoustic, Sniper Detection</td><td>Concept Number: 19</td></tr>
<tr><td colspan="5">Information Requirements
Primary Sensing Requirements: 5. Classification (caliber 5.56 to 20 mm), 6. Detection, 8. Tracking (bullet trajectory, real time), 9. Anti-sniping
Secondary Sensing Requirements:
Information Requirements: 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
Detection of two distinctive waves : the muzzle blast generated by the pressure release of the hot gazes at the mouth of the weapon and the shock wave created by the bullet when travelling at a supersonic speed.</td><td colspan="3">Illustration
</td></tr>
<tr><td>General System Description</td><td colspan="4">Using 2 Acoustic Sensors Arrays, this system not only locate in 3D the origin of the shot but also display bullet trajectory. For snipers detection, it used alone or coupled with imagers.</td></tr>
<tr><td>System Performance</td><td colspan="4">Detection of caliber 5.56 to 20 mm
Field of view: 360°*90°
Response time: lower 1.5 second
precision : +/- 2 % in bearing
+/- 20 % in range</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)</td><td>Volume</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)
Several thousand US dollars</td></tr>
<tr><td>Mobile/Stationary</td><td>Platform Type</td><td>Data Rate</td><td>Maturity (TRL)
9</td></tr>
<tr><td>CONOPS</td><td colspan="4">This device could be used in urban operation : anti-sniping, building and people protection.</td></tr>
<tr><td>Limitations</td><td colspan="4">Meteorological situation end environment can alter significantly acoustic performances (buildings, vegetation).</td></tr>
<tr><td>Critical Technologies</td><td colspan="4"></td></tr>
<tr><td>Author</td><td colspan="4">Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.
Béatrice COUDERT, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, surveillance systems.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">CLEO: Through Wall Imaging Sensor</td><td>Concept Number: 20</td></tr>
<tr><td colspan="5">Information Requirements
Primary Sensing Requirements: 5. Classification (movement or fixed people), 6. Detection, 8. Tracking (real time)
Information Requirements: 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
Through different wall (parpen, plasterboard, reinforced concrete) several persons in movement are tracked.</td><td colspan="3">Illustration
 </td></tr>
<tr><td>General System Description</td><td colspan="4">The system is composed of 3 radars on tripod and 4 acoustic-seismic sensors, all manage by a computer. On the computer, the room is drawn and the movement of people can be traced.</td></tr>
<tr><td>System Performance</td><td colspan="4">3 L band independent FM CW radars. Triangulation track processing. Seismic/acoustic sensors for interpretation aid.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)</td><td>Volume</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)</td></tr>
<tr><td>Mobile/Stationary</td><td>Platform Type</td><td>Data Rate</td><td>Maturity (TRL)
6</td></tr>
<tr><td>CONOPS</td><td colspan="4">Used as an intelligence identification/tracking of people through wall. Terrorism.</td></tr>
<tr><td>Limitations</td><td colspan="4">Can only see (through wall) when antennas are against the wall.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4"></td></tr>
<tr><td>Author</td><td colspan="4">Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.</td></tr>
</table>

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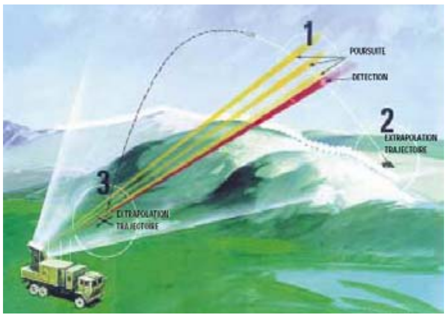
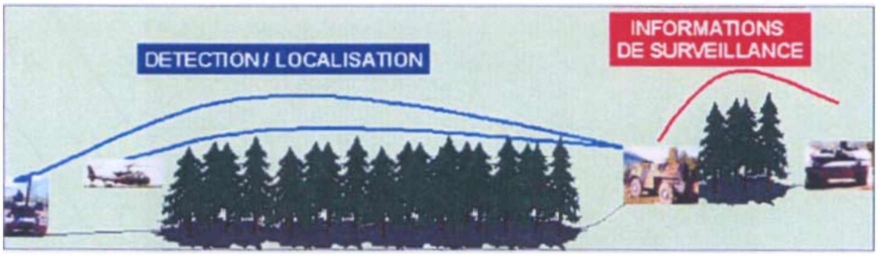
Sensor Technology	*COBRA: Counter Battery Radar*		Concept Number: 21	
Information Requirements ***Primary Sensing Requirements:*** *5. Classification (mortar), 6. Detection, 8. Tracking (shell trajectory, real time)* ***Secondary Sensing Requirements: –*** ***Information Requirements****: 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports*				
Technology Description *COBRA (Counter Battery RAdar) is a high-mobility weapon location radar with a solid-state, active, modular antenna. Integral tracking accuracy combined with 'highly efficient' clutter rejection techniques enables the system to perform 'high' accuracy location.*		***Illustration***		
General System Description	*The COBRA radar is contained in a single cross-country wheeled vehicle that incorporates an operations cabin with the radar antenna mounted on top. COBRA perform 'high' accuracy location of hostile battery positions and predict impact points within very short transmission periods.*			
System Performance	*C band. Range detection 40 km. 40 batteries can be located and reported to a higher command in less than two minutes.*			
System Specifications	***Weight (kg)***	***Volume*** *Antenna (approximately) 2.7 m * 2.4 m*	***Power Requirement***	***Estimated Cost ($ 1000)*** *Several million US dollars*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)*** *8*
CONOPS	*Could be used as an intelligence tracking of hostile battery on a city.*			
Limitations	*Sector coverage.*			
Critical Technologies				
Author	*Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.*			



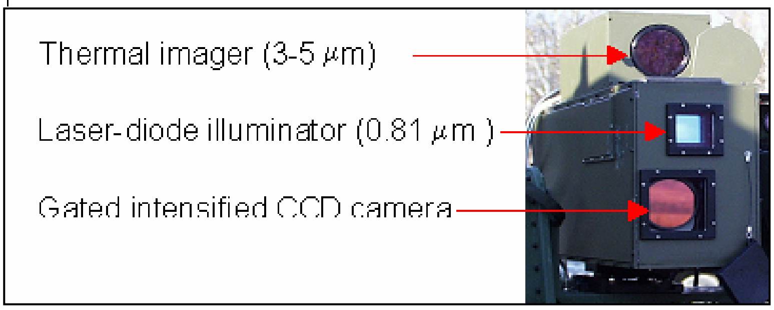
NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">CUIRACE: Foliage Penetration</td><td>Concept Number: 22</td></tr>
<tr><td colspan="5">Information Requirements
Primary Sensing Requirements: 5. Classification (wheel, tracked vehicle, helicopter), 6. Detection, 8. Tracking (real time)
Secondary Sensing Requirements
Information Requirements: 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
Pulse Doppler Waveforms. Full solid state transmission. 360° azimuth coverage (electronic switching).</td><td colspan="3">Illustration

</td></tr>
<tr><td>General System Description</td><td colspan="4">This sensor is designated to detect vehicle or helicopter hidden behind a mask or foliage.</td></tr>
<tr><td>System Performance</td><td colspan="4">UHF short range performance : class 10 km. NLOS (Non Line Of Sight) configurations including ground target detection. Small targets detection and tracking.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)</td><td>Volume</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)</td></tr>
<tr><td>Mobile/Stationary</td><td>Platform Type</td><td>Data Rate</td><td>Maturity (TRL)
6</td></tr>
<tr><td>CONOPS</td><td colspan="4">Could be used to detect vehicle or helicopter behind a mask.</td></tr>
<tr><td>Limitations</td><td colspan="4"></td></tr>
<tr><td>Critical Technologies</td><td colspan="4"></td></tr>
<tr><td>Author</td><td colspan="4">Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*DEMISTER: Detect and Locate Surface Laid and Buried Mines*			Concept Number: 23	
Sensing Requirements					
Primary Sensing Requirements: *5. Classification plastic or metallic mines (not real time), 6. Detection, 8. Tracking, 9.Recognition (surface laid or buried mines)*					
Secondary Sensing Requirements:					
Information Requirements*: 11. Sites which may be Centers of Gravity, 15. Graphic and Verbal Situation Reports*					
Technology Description *DEMISTER is a SFCW (Stepped Frequency Continue Waveform) UWB (Ultra Wide Band) radar (> 7GHz).*		***Illustration*** 			
General System Description	*DEMISTER is mounted on a wheeled vehicle. DEMISTER is able to reliably detect and locate surface laid and buried mines up to a depth of 30 cm.*				
System Performance	*Automatic detection by HR spectral. Analysis and image detection processing.* *Typical detection depth: 30cm.* *Localisation Accuracy < 10cm.*				
System Specifications	***Weight (kg)*** *< 100 kg*	***Volume***	***Power Requirement*** *500 W*	***Estimated Cost ($ 1000)***	
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)*** *6*	
CONOPS	*The system could be used in an urban operation for mine detection.*				
Limitations					
Critical Technologies					
Author	*Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical Procurement Executive, Radar Land Systems.*				

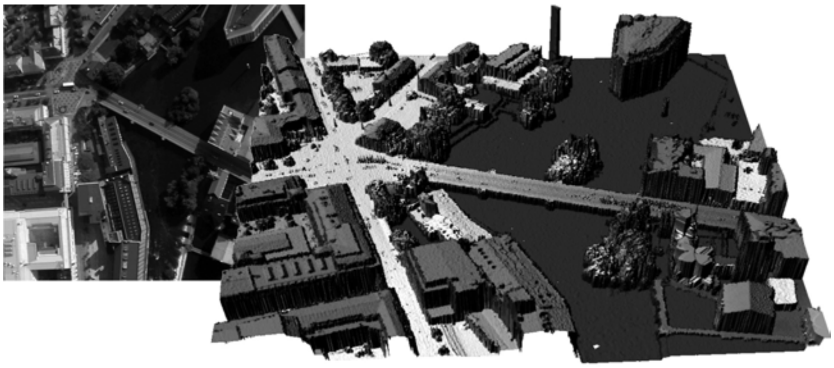
NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="4">Active Imaging Systems</td><td>Concept Number: 24</td></tr>
<tr><td colspan="6">Sensing Requirements
Primary Sensing Requirements: 1. Mapping Facilities, 2. Mapping Route, 3. Mapping Utilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking
Secondary Sensing Requirements:
Information Requirements: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 9. Foe Discrimination, 10. Prediction of Adversary Actions, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="6">Technology Description
Illustration


An active imaging system normally combines a solid-state laser diode array illuminator with a range-gated intensified camera. Active imagers proved particularly efficient at night and in degraded weather conditions. In addition, it was demonstrated that range gating, besides eliminating most of the light backscattered by aerosols, provided to some extent immunity to blooming effects (caused by the presence of bright light sources in the scene for example) specific to highly sensitive cameras. Dazzling protection against external light sources is achieved with a low duty cycle by gating the camera at high-repetition rate and by adding a narrow-band optical filter mounted in front of the lens. Another advantage of active imaging is the capability of such systems to look through windows (monitor activities inside a dark room for example), contrary to thermal imagers. The operating wavelength is often in the near-infrared portion of the spectrum, that is, between 800 and 980 nm, and consequently the illumination on the target is invisible to the naked eye. Finally, based on the retro-reflection effect, the system is capable to detect optical sights (binoculars, riflescopes, NVGs, etc.) at very long ranges.</td></tr>
<tr><td>General System Description</td><td colspan="5">An active imager in general is made up of a range-gated intensified CCD camera with a powerful zoom lens, a laser diode array illuminator and the requisite electronics for system synchronization and control. A PC provides the operator-machine interface (OMI) and furnishes status and control information overlaid on its display.</td></tr>
<tr><td>System Performance</td><td colspan="5">Depending of the application, the system is capable of either detecting optical sights almost line-of-sight, gather information and monitor activities (particularly during overcast nights or in degraded weather conditions) at many kilometer or identify a man and read a vehicle registration number at many hundreds meters (depending of the laser beam collimation and zoom lens capability).</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
20 kg</td><td>Volume
~BETACAM camera</td><td>Power Requirement
?</td><td colspan="2">Estimated Cost ($ 1000)
200</td></tr>
<tr><td>Mobile/Stationary
Both</td><td>Platform Type
Land</td><td>Data Rate
30 Hz, RS-170 video</td><td colspan="2">Maturity (TRL)
TRL 9. Commercially available</td></tr>
<tr><td>CONOPS</td><td colspan="5">See capabilities described above.</td></tr>
</table>

Limitations	*In some cases, eye safety issues must be considered. For near-infrared systems, the naked eyes NOHD turns generally around 50 m.*
Critical Technologies	*Laser diode array beam collimation.*
Author	*Vincent Larochelle, DRDC Valcartier, Tel: 418-844-4000 (ext: 4360); Vincent.larochelle@drdc-rddc.gc.ca.*

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="2">Airborne Laser Scanner (ALS)</td><td colspan="2">Concept Number: 25</td></tr>
<tr><td colspan="5">Primary Sensing Requirements: 1. Mapping Facilities, 2. Mapping Route, 3. Mapping Utilities
Secondary Sensing Requirements: 4. Identification, 5. Classification, 6. Detection
Information Requirements: 2. Mapping of the City, 4. Dynamic Route Planning, 7. Culture and Social Visualization, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity</td></tr>
<tr><td colspan="2">Technology Description
An Airborne Laser Scanner (ALS) uses a laser range finder, scanner, position (GPS) and orientation subsystem (INS) to capture detailed geometric information of the natural environment in terms of 3D point clouds. It also provides an indirect and coarse indication of material via the strength of the laser pulse return signal (wavelength dependent). New detector technology (focal plane arrays, FPA) is under development which will simplify (and sometimes replace) scanners, decrease size and power consumption an greatly increase resolution and data capture rate.</td><td colspan="3">Illustration

Aerial image and detailed (3D) elevation model for a small city area</td></tr>
<tr><td>General System Description</td><td colspan="4">ALS systems usually consists of a laser rangefinder, a scanner, a position and orientation subsystem (GPS&INS) and a computer control system. There is also a ground system for data pre- and post-processing. ALS systems is used in airborne platforms; fixed wing, helicopters and large/midsize UAV, in the future also in small UAVs. Laser scanners for UGVs is also possible.</td></tr>
<tr><td>System Performance</td><td colspan="4">For representative civil systems – laser prf is up 100 kHz, operational altitude 40-4000m depending on system and cooperation of target. Most systems obtain more then one 3D point per laser pulse, usually from first and last return. Obtainable point density on ground and area coverage rate depend on system settings, operational speed, flying altitude, area size and shape, typical examples:
1) Sampling 5 pulses/m^2, altitude 1100m, speed 100km/h => approx 2-3h/100km^2 ,
2) Sampling 1 pulses/m^2, altitude 1700m, speed 210km/h => approx 0,6-1,0h/100km^2.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
~50-80kg
(Civil system)</td><td>Volume
~0,2-0,3m^3
(Civil system)</td><td>Power Requirement
~500 W
(Civil system)</td><td>Estimated Cost ($ 1000)
0,25 and up</td></tr>
<tr><td>Mobile/Stationary
Mobile</td><td>Platform Type
Air (or ground) platform</td><td>Data Rate
Laser prf up to 100kHz (civil systems)</td><td>Maturity (TRL)
9 for repr. Systems
(6 for FPA systems)</td></tr>
<tr><td>CONOPS</td><td colspan="4">Used on UAV/UGV for detailed and rapid mapping/geographic data acquisition, also for recon and surveillance. Data processing is made in ground station after acquisition.</td></tr>
<tr><td>Limitations</td><td colspan="4">Data processing methods under development. Operations limited by weather and air defence, especially for low cost and low altitude system which spend more time over target areas.</td></tr>
</table>

Communications	*Civil systems are controlled by operational panel and on-board computer.* *A datalink is possible for future/dedicated systems.*
Critical Technologies	*Position and orientation subsystems (GPS/INS), Laser sources, Low power electronics.* *For future high performance systems – Focal Plane Array detectors.*
Author	*Dr. Ulf Söderman, Swedish Defence Research Agency (FOI), dept of Laser systems, Sweden.*

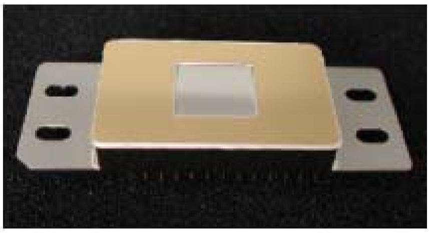
NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Near Infrared Sensor (NIR)*			Concept Number: 26

Primary Sensing Requirements: *2. Mapping Route, 3. Mapping Utilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking*

Secondary Sensing Requirements:

Information Requirements: *2. Mapping of the City, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 7. Culture and Social Visualization, 8. Buildings Layouts, 9. Foe Discrimination, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity, 13. Performance of Capability, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports*

Technology Description	***Illustration***
NIR camera features an increased sensitivity in the near-IR range that peaks at 760 nm and reaches 1200 nm. Near-IR cameras for machine vision can be based on CCD sensors.	 

General System Description	*Standard and extended wavelength 2D InGaAs detector arrays operating in the wavelength range from 0.9 to 1.7 or 2.5 micron.* *The InGaAs series of two-dimensional arrays of photodiodes is specifically suited for (NIR) near infrared imaging applications.*			
System Performance	*Arrays operating in the wavelength range from 0.9 up to 1.7 µm. The XEVA-USB digital camera is operated from one single 12V – 5A power supply (included in the configuration) and includes all voltage regulating circuits, a temperature stabilization circuit for the cooling of the detector and the signal output analog to digital conversion.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($1000)***
	Varies depending on packaging and configuration	*Varies depending on packaging and configuration*	*Varies depending on packaging and configuration*	*10 and up*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity***
				NIR TRL (9)
CONOPS				
Limitations	*Further human factors studies are required for optimal sensor/display placement on the soldier's helmet to increase the user's mobility.*			
Critical Technologies	*Electronic Image Intensifiers, Low Light Level sensor, Fusion.*			
Author	*Micheal Bentley, US Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) USA.*			

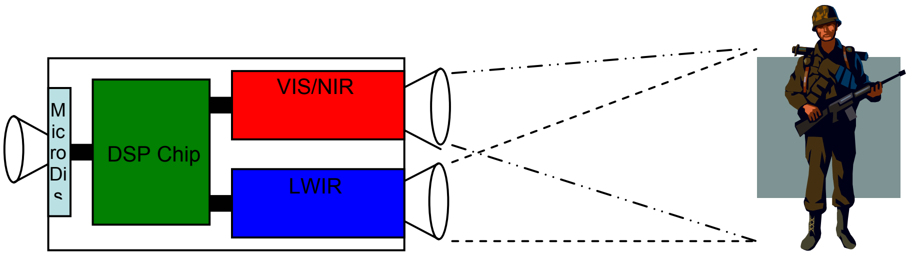
NATO SET-076/TG-44 Technology Concept Description (Template)

Sensor Technology	*Hyperspectral Imagery (Visible and Infrared)*			Concept Number: 27
Sensing Requirements ***Primary Sensing Requirements:*** *4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Other Sensing* ***Secondary Sensing Requirements:*** ***Information Requirements*** *1. Blue Force Tracking, 3. Red Force Tracking, 5. RT Surveillance of Objectives*				
Technology Description *Visible system detects reflected light, measures spectral components. IR system detects thermal radiation, measures spectral components. Combines imagery with spectral content for discrimination, relies heavily on real-time processing.*	***Illustration***			
General System Description	*Could be used for surveillance or point and interrogate; target detection, tracking, discrimination, gaseous hazards, detection of muzzle flashes.*			
System Performance	*Day/Night capability, target categorization by shape and spectral content (color or thermal pattern). Can detect various hazardous vapors and identify them.*			
System Specifications	***Weight (kg)*** *~75 kg*	***Volume*** *~0.5 cubic metre*	***Power Requirement*** *10A/115VAC*	***Estimated Cost ($ 1000)*** *0.5 and 5M$*
	Mobile/Stationary *Both*	***Platform Type*** *Vehicle or aircraft*	***Data Rate*** *2.9 Gbytes/min*	***Maturity (TRL)*** *9*
CONOPS	*Air-borne surveillance or snap shot operation from a mobile ground platform or a fixed position such as a rooftop.*			
Limitations	*Technology is still maturing. Not really man-portable.*			
Critical Technologies	*1 and 2 dimensional IR detector arrays applicable for Spectral applications, small dedicated real-time processing hardware.*			
Author	*Dr. Tracy Smithson DRDC Valcartier, Canada.*			

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">EO Imagery (Visible)</td><td>Concept Number: 28</td></tr>
<tr><td colspan="5">Sensing Requirements
Primary Sensing Requirements: 1. Mapping Facilities, 2. Mapping Route, 3. Mapping Utilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Other Sensing
Secondary Sensing Requirements:
Information Requirements: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 7. Culture and Social Visualization, 8. Buildings Layouts, 9. Foe Discrimination, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
Visible band imagery is commonly available in colour video or still format.</td><td colspan="3">Illustration</td></tr>
<tr><td>General System Description</td><td colspan="4">For urban operations, ground based imagery, or aerial imagery from UAVs, aircraft or satellites are useful.</td></tr>
<tr><td>System Performance</td><td colspan="4">Inexpensive video cameras are typically 640x480 pixels , still cameras commonly have 8 megapixel resolution.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
Optics weight dependent</td><td>Volume
Optics weight dependent</td><td>Power Requirement
mW to kW</td><td>Estimated Cost ($ 1000)
Few dollars to $k's</td></tr>
<tr><td>Mobile/Stationary
Both</td><td>Platform Type
Various</td><td>Data Rate
Kbytes to 10Mbytes</td><td>Maturity (TRL)
9</td></tr>
<tr><td>CONOPS</td><td colspan="4">Remote video surveillance, cameras in UAVs, ground-based surveillance systems, hand-held still and video cameras.</td></tr>
<tr><td>Limitations</td><td colspan="4">Visible-band imagery requires daylight or artificial lighting.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4">Mature technology, many sources of equipment.</td></tr>
<tr><td>Author</td><td colspan="4">James Cruickshank, Processing and Fusion Group, Optronic Surveillance Section, DRDC Valcartier, Canada.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Image Sensor Fusion for Soldier-Borne Applications*		Concept Number: 29	
Sensing Requirements				
Primary Sensing Requirements: *4. Identification, 5. Classification, 6. Detection* ***Secondary Sensing Requirements:*** ***Information Requirements:*** *5. RT Surveillance of Objectives, 9. Foe Discrimination, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports*				
Technology Description		***Illustration***		
A typical fused system consists of a VIS/NIR sensor for high resolution imagery and a LWIR sensor for long range target detection. In analog systems the images are additively combined. Digital systems combine the images pixel by pixel using digital signal processing and can incorporate a variety of image processing techniques and fusion algorithms.				
General System Description				
System Performance				
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	Varies depending on sensors selected, sensor configuration, fusion algorithm, etc.	*Varies depending on sensors selected, sensor configuration, fusion algorithm, etc.*	*Varies depending on sensors selected, sensor configuration, fusion algorithm, etc.*	
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
				Systems exist from TRL 4 – TRL 7
CONOPS				
Limitations	*System size, weight, power, cost. There are also issues with image registration and parallax in dual aperture systems.*			
Critical Technologies	*Electronic Image Intensifiers, Low Light Level sensors, SWIR sensors, uncooled microbolometers, micro displays.*			
Author	*Micheal Bentley, US Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) USA.*			

NATO SET-076/TG-44 Technology Concept Description

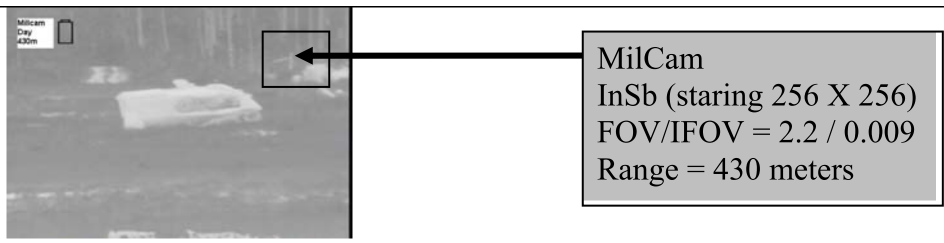
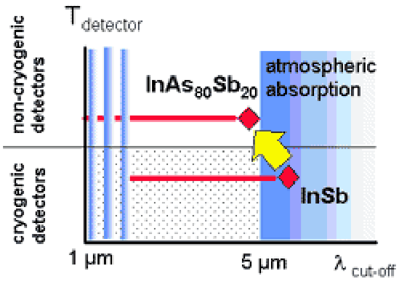
Sensor Technology	*Mid-Wavelength Infrared Sensors (MWIR)*	Concept Number: 30

Sensing Requirements

Primary Sensing Requirements: *2. Mapping Route, 3. Mapping Utilities, 4. Identification, 5. Classification, 6. Detection, 8. Tracking*

Secondary Sensing Requirements:

Information Requirements: *2. Mapping of the City, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 7. Culture and Social Visualization, 8. Buildings Layouts, 9. Foe Discrimination, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity, 13. Performance of Capability, 14. Identification of People and Equipment in Real-Time, 15. Graphic and Verbal Situation Reports*

Technology Description	***Illustration***
The medium wavelength IR (MWIR or MIR) band (3.3-5.0 µm) also offers nearly 100% transmissions, with the added benefit of lower, ambient, background noise.	 

General System Description	*Currently SMaRTS provides fused imager from IICCD and LWIR for (FY06) MWIR and LWIR will be evaluated to determine to which provides optimized imagery for mobility for targeting and reduce power, size and weight.*
System Performance	*By increasing the bandgap of InSb, which is done by producing InAsSb material, the operating temperature of the detector increases without losing important spectral information, In this way, thermoelectric cooling can provide InAsSb detectors of sufficient performance for certain applications. Furthermore, this also results in other advantages such as compactness and reduced cost.*

System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	4.5lbs		*6W output*	*20*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
				MWIR Sensor (TRL5)

CONOPS	
Limitations	*Further human factors studies are required for optimal sensor/display placement on the soldier's helmet to increase the user's mobility.*

Critical Technologies	*Detector arrays operating in the 3.0 to 5.0 micron wavelength region based on InAsSb compound semiconductors are under development.*
Author	*Micheal Bentley, US Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) USA.*

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">Compact Atmospheric Sounding Interferometer (CATSI)</td><td>Concept Number: 31</td></tr>
<tr><td colspan="5">Sensing Requirements
Primary Sensing Requirements: 4. Identification, 5. Classification, 6. Detection, 8. Tracking, 9. Other Sensing
Secondary Sensing Requirements:
Information Requirements: 5. RT Surveillance of Objectives, 10. Prediction of Adversary Actions, 15. Graphic and Verbal Situation Reports</td></tr>
<tr><td colspan="2">Technology Description
Passive standoff Long Wave IR chemical vapors sensors (7-14 micron).</td><td colspan="3">Illustration
</td></tr>
<tr><td>General System Description</td><td colspan="4">Area surveillance for chemical threat, Detection and Identification of chemical warfare agent and toxic industrial compound.</td></tr>
<tr><td>System Performance</td><td colspan="4">Detection, identification and quantification of a tactical chemical vapor cloud at up to 5km.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
< 50 kilos</td><td>Volume
< 1 meter cube</td><td>Power Requirement
300 W</td><td>Estimated Cost ($ 1000)
$250k – 350k</td></tr>
<tr><td>Mobile/Stationary
Stationary</td><td>Platform Type
Tripod</td><td>Data Rate
0.1-1 Mbits</td><td>Maturity (TRL)
TRL 6. System presently under engineering development for military operation</td></tr>
<tr><td>CONOPS</td><td colspan="4">Ground used, recon, surveillance, detection, ID and quantification of chemical threat. Used by soldiers for recon, surveillance of industrial plants.</td></tr>
<tr><td>Limitations</td><td colspan="4">Cannot see through glass, walls and water. Performance degradation at low scene thermal contrast.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4">Need of cryo-cooled detector with higher responsivity. Low power electronics, common power source.</td></tr>
<tr><td>Author</td><td colspan="4">Hugo Lavoie and Jean-Marc Thériault (Project Leader), Spectral Imaging Group, Defence Research and Development Canada (DRDC) – Valcartier, CAN.</td></tr>
</table>

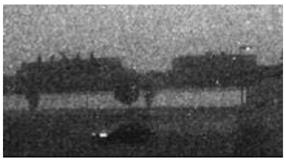
NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Short Wave Infrared (SWIR) Sensors*	Concept Number: 32
Sensing Requirements		

Primary Sensing Requirements: *4. Identification, 5. Classification, 6. Detection, 8. Tracking*

Secondary Sensing Requirements:

Information Requirements: *9. Foe Discrimination, 14. Identification of People and Equipment in Real-Time*

Technology Description	***Illustration***
SWIR detectors and cameras can see objects with better resolution than thermal cameras and they can see them through glass. They can transmit digital signals more readily than current Image Intensifiers and are more sensitive than Image Intensifiers coupled to CCDs. The SWIR spectral region has up to seven times more energy from starlight and night sky glow than any other spectral region making them very interesting for a variety of night time applications. SWIR cameras can see in a spectral band where Intensifiers cannot.	NIR Image   LWIR Image  SWIR Image  **SWIR Camera**

General System Description	*A SWIR camera is mounted on a helmet to produce a real-time image.*			
System Performance	*Provides a system that operates in the 0.9nm to 1.7 nm band which is outside the spectral range of Image Intensifiers. It operates at room temperature and has a 320 x 256 FPA, square 25 micron pixels, with high sensitivity.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	<70g	*< 26 cm^3*	*< 1.2 W*	*20*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
				SWIR cameras are commercially available
CONOPS	*Used for covert operations.*			
Limitations	*Range is currently limited to less than 50 meters and operational temperature is between 5 and 35 degrees centigrade.*			
Critical Technologies	*Higher temperature FPAs and lower noise read-out electronics.*			
Author	*Micheal Bentley, US Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) USA.*			

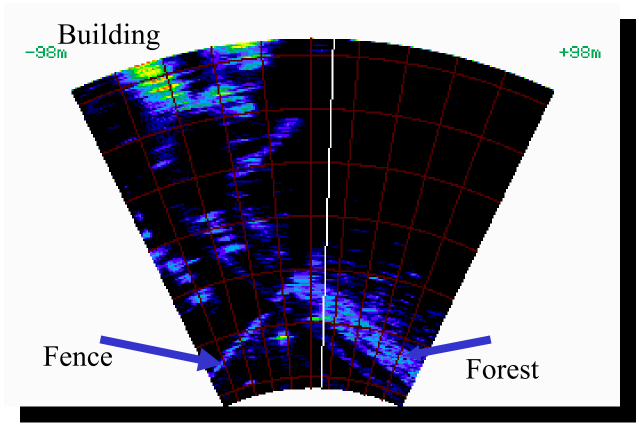
NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Active Millimeter-Wave Sensor*	Concept Number: 33

Primary Sensing Requirements: *2. Mapping Route, 6. Detection, 4. Identification*

Secondary Sensing Requirements: *5. Classification*

Information Requirements*: 4. Dynamic Route Planning, 8. Buildings Layouts, 2. Mapping of the City*

Technology Description	***Illustration***
Short range high resolution in 3D. Transmit millimeter-wave signal that interact with differently with organic and non-organic material. Detect presence of building, vehicle and peoples. Use very low transmitted power.	. 

General System Description	*Use installed on vehicle. Four sensors installed on vehicle corner to scan 360 deg.*			
System Performance	*Range resolution : 20 cm, Azimuth and elevation resolution: < 1deg.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement*** *~ 100 W*	***Estimated Cost ($ 1000)*** *10 K*
	Mobile/Stationary	***Platform Type*** *Vehicle*	***Data Rate*** *2 Hz*	***Maturity (TRL)***
CONOPS	*Used on convoy support vehicle for mapping/surveillance in all weather conditions. On surveillance post can provide alarm on any change in the scan area.*			
Limitations	*Do not provide easy interpretation display. Required trained user. Performance depends on the control of false alarms.*			
Critical Technologies	*Highly integrated millimeter receivers and transmitter are now mature. High density and high speed processor are also mature.*			
Author	*Yves de Villers, DRDC Valcartier, Canada.*			

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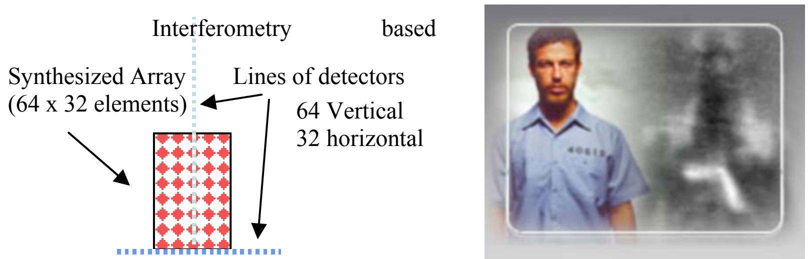
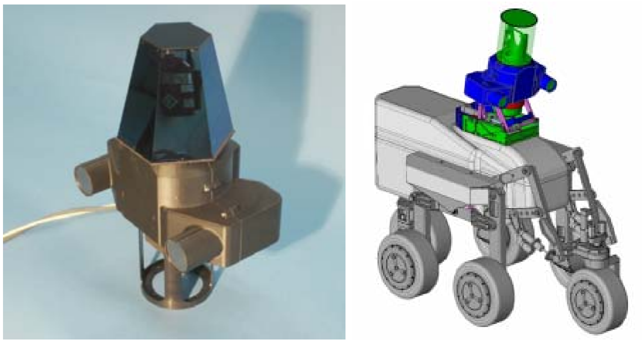
Sensor Technology	*Passive Real-Time Millimeter-Wave Imager*			Concept Number: 34
Sensing Requirements ***Primary Sensing Requirements:*** *4. Identification, 5. Classification, 6. Detection* ***Secondary Sensing Requirements:*** *1. Mapping Facilities, 2. Mapping Route* ***Information Requirements****: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 8. Buildings Layouts, 14. Identification of People and Equipment in Real-Time*				
Technology Description *Millimeter-wave signals are emitted naturally by the body and capture by the imaging sensor. The blockage of this signal by any metal or plastic material will produce an image of this object.*		***Illustration*** 		
General System Description	*Used in security check point to detect any weapon conceived under subject clothing.*			
System Performance	*Resolutions of 32 x 64 pixels. Up to 5 images per seconds could be produces.*			
System Specifications	***Weight (kg)***	***Volume*** *2m x 1m x 1m*	***Power Requirement***	***Estimated Cost ($ 1000)*** *50 and up*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
CONOPS	*Used in check point and building entrance to detect any concealed weapons.*			
Limitations	*Require the rotation of the subject to cover all the body.*			
Critical Technologies	*Integrated millimeter receiver noise figure and bandwidth.*			
Author	*Yves de Villers, DRDC Valcartier, Canada.*			

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">UWB Through-Wall Radar</td><td>Concept Number: 35</td></tr>
<tr><td colspan="5">Sensing Requirements
Primary Sensing Requirements: 1. Through-wall Mapping Facilities, 8. Through-wall Tracking, 6. Through-wall Detection
Secondary Sensing Requirements:
Information Requirements: 1. Blue Force Tracking, 3. Red Force Tracking, 8. Buildings Layouts, 10. Prediction of Adversary Actions, 11. Sites which may be Centers of Gravity</td></tr>
<tr><td colspan="2">Technology Description
UWB radar transmits high-resolution electromagnetic wave at X-bands that can propagate through-walls.</td><td colspan="3">Illustration
A drawing or a picture to illustrate the sensor technology and its use.</td></tr>
<tr><td>General System Description</td><td colspan="4">The through-wall radar is compact enough to be hand carry by a soldier or installed on a small robot.</td></tr>
<tr><td>System Performance</td><td colspan="4">Detection range up to 100m, resolution 6cm in range and 2 degree in azimuth.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
10kg</td><td>Volume</td><td>Power Requirement</td><td>Estimated Cost ($ 1000)</td></tr>
<tr><td>Mobile/Stationary</td><td>Platform Type</td><td>Data Rate</td><td>Maturity (TRL)</td></tr>
<tr><td>CONOPS</td><td colspan="4">Used on a robot for through-wall mapping, detection and tracking of human beings within building.</td></tr>
<tr><td>Limitations</td><td colspan="4">Cannot penetrate through solid metallic walls.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4">Stable transmitter.</td></tr>
<tr><td>Author</td><td colspan="4">Mr Sylvain Gauthier, Defence Scientist, Defence R&D Canada – Ottawa.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description (Template)

Sensor Technology	*Volumetric Sensor for Mobile Robotics in Complex Terrain*			Concept Number: 36
Sensing Requirements ***Primary Sensing Requirements:*** *3. Mapping Utilities, 8. Tracking, 9. modeling* ***Secondary Sensing Requirements:*** *6. Detection* ***Information Requirements****: 2. Mapping of the City, 4. Dynamic Route Planning, 5. RT Surveillance of Objectives, 8. Buildings Layouts*				
Technology Description *The volumetric sensor is a compact sensor head that combines a wide baseline stereo camera and a laser scanner with a full 360 degree azimuth and 55 degree elevation field of view allowing a robot to view and manage overhang obstacles as well as obstacles located at ground level. Information provided by the sensor will be fed into navigation and exploration modules of the robot.*	***Illustration*** 			
General System Description	*Robot sensor head providing 3D data for navigation and robotics task in complex terrain.*			
System Performance	*Up to 50,000 3D points/second from -45° to +10°, 360° all-around the robot. Stereo camera: 30°FOV 1024x1024 B&W camera link CCD camera – 1Hz 3D extraction images.*			
System Specifications	***Weight (kg)*** *5Kg*	***Volume*** *32Hx30Wx15*	***Power Requirement*** *24V,1.5A*	***Estimated Cost ($ 1000)*** *15,000USD*
	Mobile/Stationary *Mobile*	***Platform Type*** *Mid to large size robot*	***Data Rate*** *50,000 pps*	***Maturity (TRL)*** *4*
CONOPS	*Caves, rubbles exploration, EOD, IED removal, Mule (transport).*			
Limitations	*Dense atmospheric particles cloud and rain.*			
Critical Technologies				
Author	*Benoit Ricard, DRDC Valcartier, Canada (benoit.ricard@drdc-rddc.gc.ca).*			

NATO SET-076/TG-44 Technology Concept Description (Template)

Sensor Technology	*Short-Range BioSpectra: Surveillance of Bioaerosols in Large Indoor and Semi-Enclosed Outdoor Spaces*	Concept Number: 37

Sensing Requirements

Primary Sensing Requirements: *6. Detection*

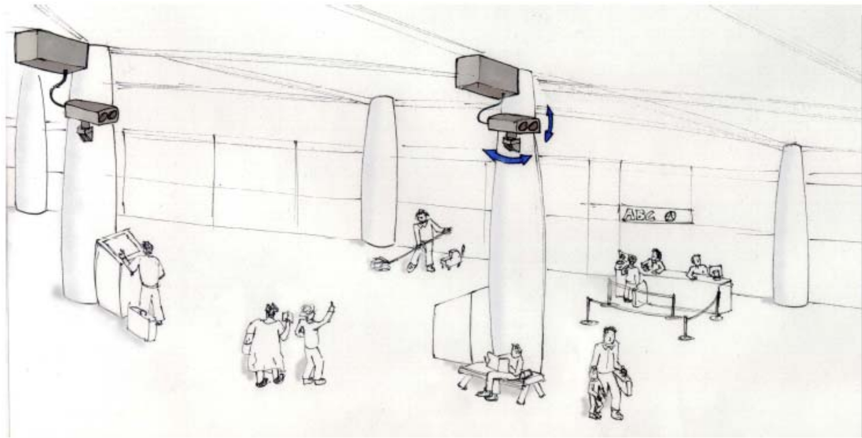
Secondary Sensing Requirements: *5. Classification*

Information Requirements*: 6. Communications, 11. Sites which may be Centers of Gravity*

Technology Description

Compact Light Detection And Ranging (LIDAR) system based on the spectrometric detection of laser-induced fluorescence to monitor large indoor and semi-enclosed outdoor spaces for biological threats in aerosol form.

Illustration



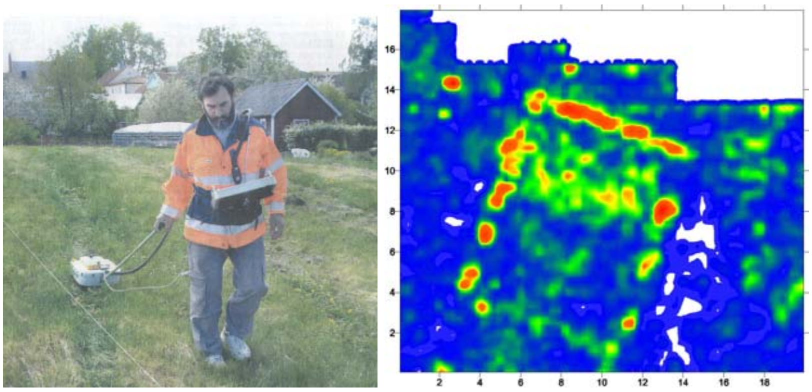
General System Description	*Provide an important and completely new capability in the CBRN surveillance and alert management over critical indoor and semi-enclosed outdoor wide areas. The system can work in areas where there is a human presence because it is eye safe and several square kilometre surfaces of various geometric complexities can be monitored by networking multiple devices. This device will provide warnings and alarms on a 24 h / 7 day-a-week basis for the presence of unusual concentrations of fluorescing aerosols at a precise remote location within the monitored area at any time and within seconds. To reduce the false positive alarm rate to an acceptable operational level, the device analyzes the spectral content of the detected fluorescence signal and classifies correctly with high probability the type of aerosols at the origin of that fluorescence. The SR-Biospectra can be combined with other technologies like point detectors sent to the reported site for more detailed information on the event or used as an asset in the evacuation planning of a large indoor and semi-enclosed outdoor spaces.*			
System Performance	*Limit of detection below 1000 CFU/Litre for distances up to 100 metres.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	<20 kg	*<12 litres*	*<300 Watts*	*$50k*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Stationary	*None*	*<5 KHz*	*3*
CONOPS	*Unknown. Similar technology including long range cloud mapping is presently in development.*			
Limitations	*Do not do biological threat identification.*			

Critical Technologies	*Library of fluorescing spectra. Presently in development.*
Author	*Jean-Robert Simard, Group head, Spectral imaging, Optronic Surveillance, DRDC Valcartier, Canada.*

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*SPYBOWL FELIN's Optronic Ball*		Concept Number: 38	
Information Requirements ***Primary Sensing Requirements:*** *4. Identification, 6. Detection, 8. Tracking* ***Secondary Sensing Requirements:*** *1. Mapping Facilities* ***Information Requirements****: 5. RT Surveillance of Objectives, 8. Buildings Layouts, 14. Identification of People and Equipment in Real-Time, 11. Sites which may be Centers of Gravity*				
Technology Description *Spybowl integrates four miniaturized cameras (enabling a full omnidirectional view), a microphone, a lithium-ion battery (providing an autonomy of 1 hour), and an HF radio for data transmission in a range of up 30 m inside buildings and 100 m in open areas.*	***Illustration***   			
General System Description	*Spybowl is a handheld "robot" designed to be as simple and as ruggedized as possible. It has been developed for use by infantry troops or special forces operatives in potentially dangerous confined areas, such as buildings and caves.*			
System Performance	*This lightweight "optronic ball" which can be rolled or thrown like a grenade, instantaneously provides the soldier with a 360 degree view of the scene.* *All components are packed inside an aluminum structure coated with rubber, which enables Spybowl to sustain severe and repetitive shocks.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost*** *Not significant*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)*** *6*
CONOPS	*In an urban operation, SPYBOWL can be designated to investigate potentially dangerous confined areas, such as buildings and caves.*			
Limitations	*SPYBOWL is not equipped with IR or IL sensors yet.*			
Critical Technologies				
Author	*Morgan BRISHOUAL, DGA/SPART, French MoD/Land armament program department, Technical procurement executive, radar land systems.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Ground Penetrating Radar*			Concept Number: 39
Primary Sensing Requirements: *1. Mapping Facilities, 6. Detection* ***Secondary Sensing Requirements:*** *5. Classification* ***Information Requirements****: 8. Buildings Layouts, 15. Graphic and Verbal Situation Reports*				
Technology Description *Ground penetrating radars (GPR) often work in 100 MHz –2 GHz regime where the penetration of radar waves into the ground and concrete building structures often is good. GPR can be used for mine detection and for location of tunnels, pipes, cables, metallic and other objects. Hidden layers, structures and cavities below the ground level or behind walls can also be imaged.*		***Illustration***  *Mapping of below ground level structures and objects using GPR.*		
General System Description	*Low frequency radar used for detection and mapping of below ground objects, structures and cavities.*			
System Performance	*Areas > 100 m^2 / h can be mapped. Image resolution down to approximately 0.2 m x 0.2 m.*			
System Specifications	***Weight (kg)*** *> 10 kg*	***Volume*** *0.2 x 0.2 x 0.2 m.*	***Power Requirement*** *100 W*	***Estimated Cost ($ 1000)*** *> 1*
	Mobile/Stationary *Mobile*	***Platform Type*** *Portable device*	***Data Rate*** *Application and resolution dependent*	***Maturity (TRL)*** *6-9*
CONOPS	*Mapping and detection of below ground level objects and structures such as mines, UXO, other explosives, cables, pipes and tunnels can be made.*			
Limitations	*Sufficiently low frequencies must be used (< 2 GHz) for good penetration. The penetration depth of radar waves is limited in water rich ground layers.*			
Communications	*An experienced operator is needed on site for real time image analysis.*			
Critical Technologies	*Low power and low weight radar electronics required for portable devices.*			
Author	*Johan Rasmusson, Dept. of Sensor Technology, FOI, Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Multi-Sensor Chain for Border Surveillance*	Concept Number: 40

Primary Sensing Requirements: *2. Mapping Route, 5. Classification, 6. Detection, 8. Tracking*

Secondary Sensing Requirements: *–*

Information Requirements*: 3. Red Force Tracking, 5. RT Surveillance of Objectives, 12. Request for Support, 14. <Identification of People and Equipment in Real-Time*

Technology Description	***Illustration***
Sensing the reflections of electromagnetic waves from moving and stationary targets. Utilization of the Doppler effect and changes between observations for detection and localization of possible targets. Optical system senses the natural reflections in the visual band or the natural reflections and emissions in the ir-region.	

General System Description	*The system consists of several slightly elevated radars and optical sensors forming a chain searching an area around a borderline. The radar guide high resolution optical systems for threat analysis. Search results are communicated through the sensor line to suitable located command posts.*			
System Performance	*The radar range against moving human beings is supposed to be around 2-10 km depending on the geometrical sight conditions. The optical system is designed for threat analysis in a high-resolution mode. Precipitation and fog will limit the operation of optical systems.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	100 kg	*100-200* dm^3		
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Stationary	*Mast or tripod*	*1 Hz*	*9*
CONOPS	*The system is applicable for the surveillance of restricted areas around a borderline. The system is capable to detect and locate intruders and provide optical images to command posts or centers for further action. Border line examples are: borders between countries, electrical power lines, oil pipes, fences, streets etc.*			
Limitations	*Precipitation and fog will limit the operation of optical systems and geometrical sight limits the system in general.*			
Communications	*Radio link system utilizing the surveillance sensor positions.*			
Critical Technologies				
Author	*Jan Kjellgren, FOI, Dep. of Sensor Technology, Linköping, Sweden.*			

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*Combined Millimeter/Optical Stand-Off Check Point System*	Concept Number: 41

Sensing Requirements

Primary Sensing Requirements: *4. Identification, 5. Classification, 6. Detection*

Secondary Sensing Requirements: –

Information Requirements*: 14. Identification of People and Equipment in Real-Time*

Technology Description

The millimeter wave system senses the reflected or the thermally generated field at millimeter waves and the optical system senses the natural reflections in the visual band or the natural reflections and emissions in the ir-region. Clothing on humans is normally transparent at millimeter waves and objects beneath cloth influence the IR signature.

[1] R. Doyle, B. Lyons, A. Lettington, T. McEnroe, J. Walshe, J. McNaboe, P. Curtin, and S. Bleszynski, "Stand-off detection of hidden threat objects on personnel at checkpoints and in public areas using active millimetre-wave imaging," Passive Millimetre-Wave and Terahertz Imaging and Technology, London, UK, 2004.

The figure shows a merged image calculated from optical and radiometric data. The data of the separate images is collected from figures in the paper by R Doyle et al [1].

General System Description	*The system consists of a millimeter wave radar/radiometer operating at 220 GHz combined with a passive optical system. The radar/radiometer has multiple receivers. To be able to identify a person the optical system will be operated in a high resolution mode guided by the radar/radiometer.*			
System Performance	*The radar range against concealed small arms is estimated to be 30 m. Cross range resolution is about 1 dm at 30 m. The optical system is designed for identification or classification of personnel at 30 m (angle resolution ≈ 0.3 mrad. The radar/radiometer has a field of view of 0.1 sterrad and an update rate between 1-10 Hz. The system is supposed to be transported by two men and mounted on a tripod or operated from a small vehicle.*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	25-50 kg	*100-200 dm^3*		*10-50 (Large series)*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Stationary	*Tripod or vehicle*	*1-10 Hz*	*2*
CONOPS	*The system is applicable for surveillance of people in small public areas in and outdoors and at stand off checkpoints. It will facilitate the detection of people carrying concealed weapons and bombs.*			
Limitations	*The radar/radiometer cross-range resolution limits the operational range. For still higher frequencies between 500-1000 GHz the atmosphere will also limit the range. Precipitation and fog will limit the operation of optical systems.*			

Critical Technologies	*The most critical components or subsystems limiting the performance of millimeter wave systems are sources, detectors and antenna system. At present there are ongoing research efforts to develop systems at 220 GHz.*
Author	*Jan Kjellgren, FOI, Dep. of Sensor Technology, Linköping, Sweden.*

NATO SET-076/TG-44 Technology Concept Description

<table>
<tr><td>Sensor Technology</td><td colspan="3">Active Defence Sensor System</td><td>Concept Number: 42</td></tr>
<tr><td colspan="5">Primary Sensing Requirements: 6. Detection, 8. Tracking
Secondary Sensing Requirements: –
Information Requirements: 10. <Prediction of Adversary Actions, 13. <Performance of Capability></td></tr>
<tr><td colspan="2">Technology Description
The radar reflections from projectiles and missiles threatening a combat vehicle. A suitable coherent waveform and a corresponding antenna system is employed for detection and tracking. In a multi-sensor system also the thermal radiation can be used.
The figure shows Arena E Active Protection System installed on T-80U (from Int. Online Defence Magazine 2004 issue 1).</td><td colspan="3"></td></tr>
<tr><td>General System Description</td><td colspan="4">The system consists of a coherent microwave wave radar or a radar combined with a passive IR-system. The radar has multiple receivers to achieve the necessary tracking accuracy and coverage.</td></tr>
<tr><td>System Performance</td><td colspan="4">The system is supposed to be mounted on combat vehicles for the protection against projectiles and missiles. The radar range is estimated to be around 100-200 m. The threat must be predicted for a time around 10 ms with a spatial 3D accuracy of the order 1 dm^3.</td></tr>
<tr><td rowspan="2">System Specifications</td><td>Weight (kg)
50-200 kg excl. def. mech.</td><td>Volume
20 – 100 dm^3</td><td>Power Requirement
50-500 W</td><td>Estimated Cost ($ 1000)
50-500</td></tr>
<tr><td>Mobile/Stationary
Mobile</td><td>Platform Type
Armored vehicle</td><td>Data Rate
> 1 kHz</td><td>Maturity (TRL)
5-8</td></tr>
<tr><td>CONOPS</td><td colspan="4">The system is applicable for the protection of vehicles against rocket propelled grenades fired at short ranges in urban areas. This type of system will probably be able to counteract KE-projectiles in the future.</td></tr>
<tr><td>Limitations</td><td colspan="4">There is a more or less severe weapon effect of the threat left after the counteraction. This effect the vehicle must withstand. There are also a risk for collateral damages which could limit the activation of the system.</td></tr>
<tr><td>Communications</td><td colspan="4">How to communicate with the sensor.</td></tr>
<tr><td>Critical Technologies</td><td colspan="4">Antenna techniques, system design, signal processing and the defence mechanization including launching and intercept functions.</td></tr>
<tr><td>Author</td><td colspan="4">Jan Kjellgren, FOI, Dep. of Sensor Technology, Linköping, Sweden.</td></tr>
</table>

NATO SET-076/TG-44 Technology Concept Description

Sensor Technology	*3-D Ladar for UAV (or Ground Vehicle)*	Concept Number: 43

Primary Sensing Requirements: *1. Mapping Facilities, 2. Mapping Route, 3. Mapping Utilities, 4. Identification, 5. Classification*

Secondary Sensing Requirements: *6. Detection, 8. Tracking, 9. Other Sensing*

Information Requirements*: 1. Blue Force Tracking, 2. Mapping of the City, 3. Red Force Tracking, 4. Dynamic Route Planning, 14. Identification of People and Equipment in Real-Time*

Technology Description	***Illustration***
3-D laser radar (ladar) gives a high resolution 3-dimensional image.	

General System Description	*Mounted on small UAV/UGV. Staring 3-D ladar at 1.5 µm wavelength.*			
System Performance	*Resolution at target 5-10 cm (x,y,z). Frame rate 10-25 Hz. Range: ~km (several km with more laser power in larger systems).*			
System Specifications	***Weight (kg)***	***Volume***	***Power Requirement***	***Estimated Cost ($ 1000)***
	20	*Shoe box*	*300 W*	*50 and up*
	Mobile/Stationary	***Platform Type***	***Data Rate***	***Maturity (TRL)***
	Mobile	*UAV (can also be mounted on UGV or ground vehicle)*	*10-100 MB/s*	*5 (staring system)* *9 (scanning system)*
CONOPS	*ID of targets (obscured and/or camouflaged) that have been previously detected by another sensor, or surveillance of a limited area (e.g. along a street). Day/night capacity. 3-D data gives classification and ID with high confidence.*			
Limitations	*Degraded range performance in fog and haze.*			
Communications	*1) Real time video link to operator.* *2) Low bandwidth link for target info (requires signal processing on platform).* *3) None. All data is recorded on disc for off-line processing.*			
Critical Technologies	*Focal plane array detector for staring capability.*			
Author	*Dr. Dietmar Letalick, FOI (Swedish Defence Research Agency), Division of Sensor Technology.*			

Annex B – VIGNETTES

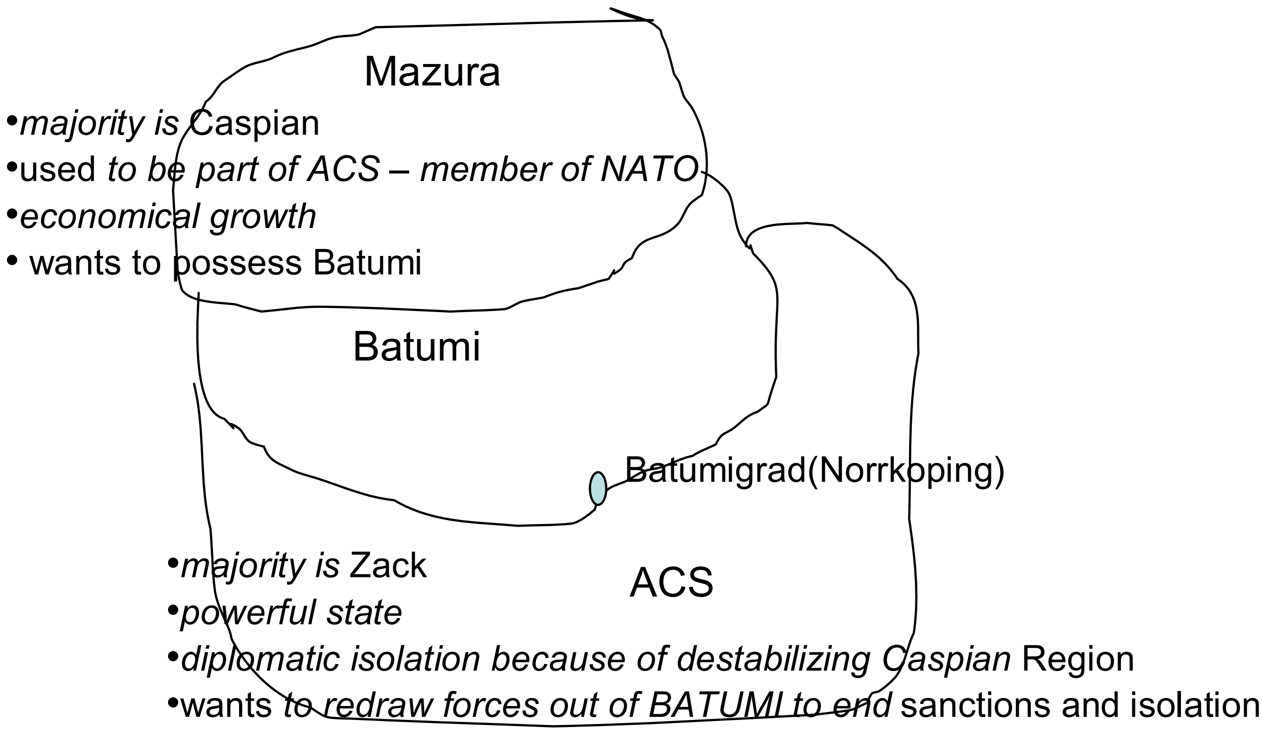
B.1 NATO WORKSHOP SET-090 RWS06 MSE

The following text is based on vignettes from a work done by IST-046 / RTG-018 "Command Center Challenges for Urban Operations" dated 1st of March 2004 with the reference of Belinda Smeenk TNO Pysiseh en Eleiitronisch Laboratorium.

The Vignettes are transformed from the use of DigNor (Digital Norrköping) as a tool for the SET-090 RWS06 MSE workshop Sensors Technology for the Future Dismounted Warrior and Sensors for Urban Operations in Shrivenham, United Kingdom, Monday 18 Sep 2006 – Thursday 21 Sep 2006. We have also put together an annex of Equipment to meet in Batumigrad.

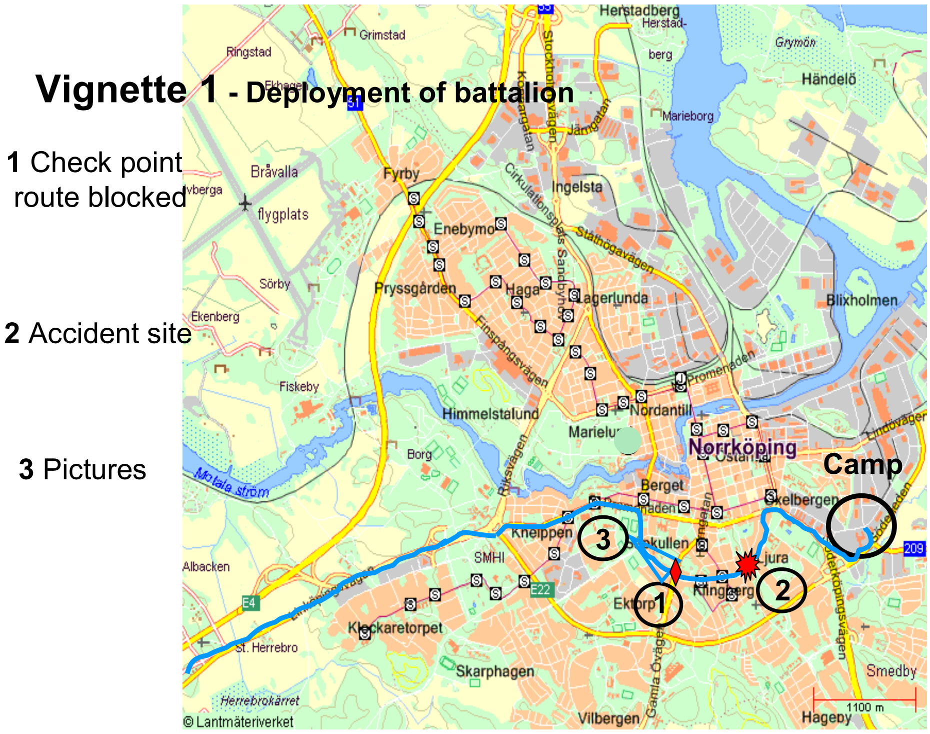
B.1.1 Context

Tensions exist in BATUMI which is the province of the Alliance of Caucasus States (ACS). ACS and neighbor state MAZURA have both want to control BATUMI for years. ACS invaded the South of MAZURA in 2015. NATO forces defeated this attack. After elections in 2024 ACS moderates replaced the radical party. They agreed to conduct a phased withdrawal of the ACS forces out of BATUMI. In exchange for this the ACS leadership wanted to secure monetary loans, make a goodwill gesture to the UN and international community and they hoped that the Bowl groups would stop with terrorist attacks etc. The ACS forces would withdraw and NATO forces would replace the ACS forces in BATUMI. Forces of MAZURA would stay out of BATUMI. However not all Zack people supported this idea and a lot of Zack people deserted the ACS forces.

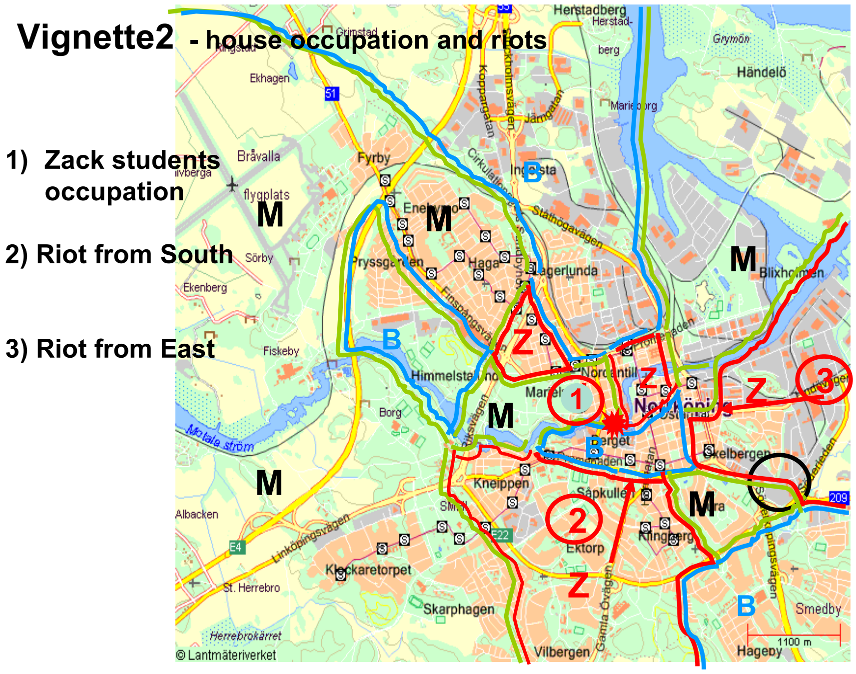


B.1.2 Vignettes

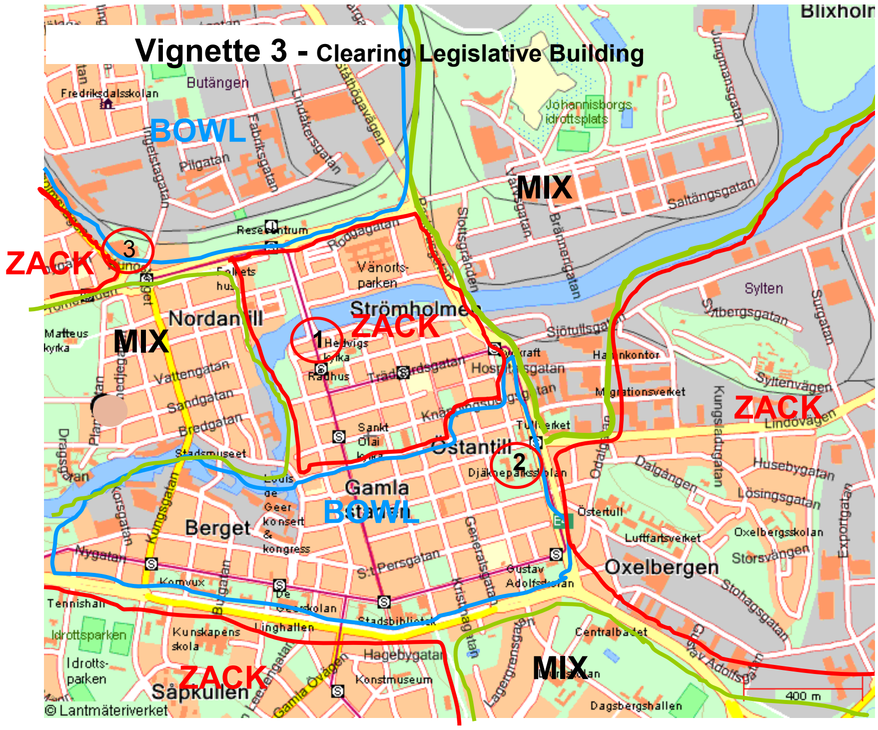
Vignette One: Deployment of battalion in Batumigrad/Norrkoping without large opposed threats (Crisis Response Operations).



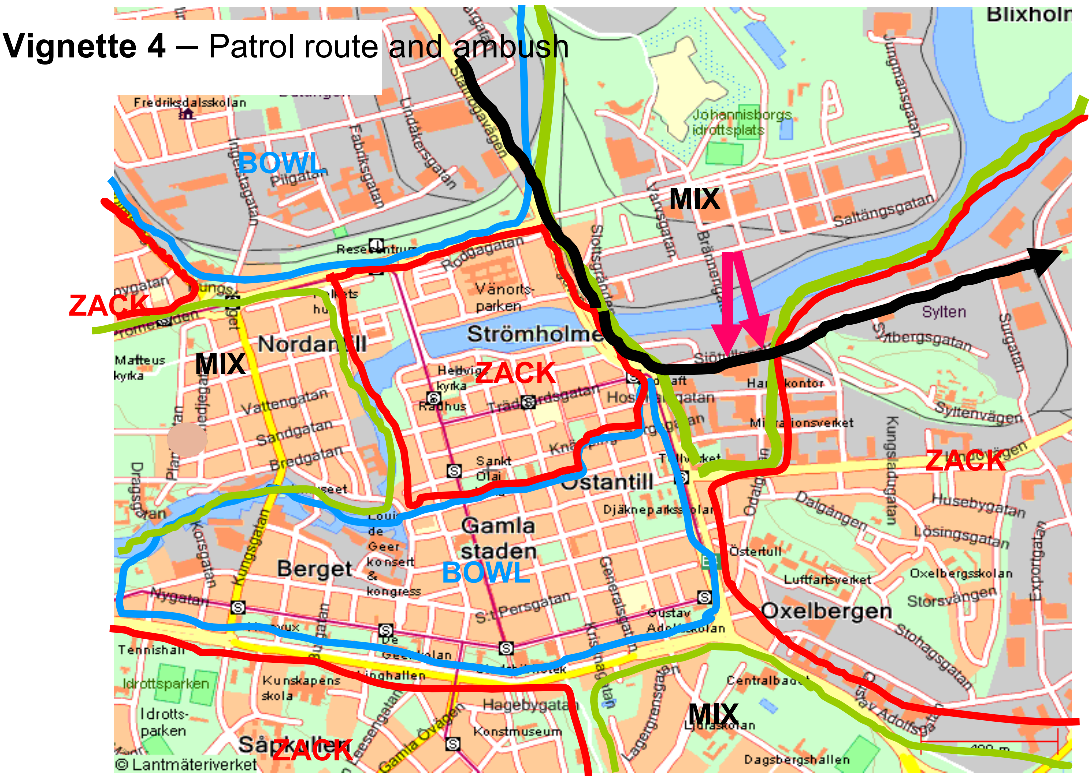
Vignette Two: Riots at the university main campus and an attempt of Zack factions to expand their control over important Batumigrad/Norrkoping sites (Defensive operation).



Vignette Three: NATO forces attempt to regain the area controlled by ZLF and ACS deserters (Offensive operation).



Vignette Four: Surveillance and patrolling in Batumigrad/Norrkoping (Humint operation).



	Vignette One: Deployment of battalion in Batumigrad/ Norrkoping without large opposed threats (Crisis Response Operations)	**Vignette Two: Riots at the university main campus and an attempt of Zack factions to expand their control over important Batumigrad/Norrkoping sites (Defensive operation)**	**Vignette Three: NATO forces should regain the area controlled by ZLF and ACS deserters (Offensive operation)**	**Vignette Four: Surveillance and patrolling in Batumigrad/Norrkoping (Humint operation)**
Context	In this vignette the NATO peacekeeping battalion will set up a compound for the battalion in Batumigrad/Norrkoping. The battalion has the responsibility of an area in the city with a majority of Zack population. The building for the compound is already chosen and inspected. First a provisional battalion command post will be created. The first company and a Sense platoon will take care of the security in the area around the compound. The second company will organize the situation at the compound and the first company will patrol the BG AOR. The third company is BG reserve.	After a week of riots at the university campus the intensity of the riots were enlarged by the assassination of a high Zach Loyalist Party (ZLP) official. The Zach Loyalist Forces (ZLF) are shooting Bowl students at the campus. The heavy weapons of the ACS deserters are stored at a NATO controlled site, however, a large amount of manportable weapons are still available to ZLF and ACS deserters. The NATO BG commander is on speaking terms with the leader of ZLP Mrs. Maria Cliver. The Batumi Police Force is active and cooperating with NATO forces. The Batumigrad/Norrkoping police can muster a platoon for crowd and riot control. However policemen receive only a small pay and cannot be completely trusted to be impartial. The Quick Reaction Force (QRF) platoon of the battalion has detected this shooting and reports that some hundreds of people are involved in this incident. Civilian casualties are being evacuated in civilian ambulances. The international press provides live TV pictures of the event.	After the riots the ZLF and ACS deserters have seized the Provincial Legislative Buildings (Vig3, building 2 and 3) and they now control downtown former Bowl-area and approaches to it. Additional street barricades and the presence of small crowds of angry Zack civilians are present. The BFF are attacking the Zack civilians and cultural sites. An unknown faction has seized a weapon storage site and heavy weapons are under their control. The battalion has to regain the control of this area to create a stable situation again. The ZLF and ACS deserters have prepared barricades and are present at all corners of the area around the Provincial Legislative Building. They might also be present in and on the buildings. The battalion will try to isolate the area and expand control.	In this vignette the battalion will be on patrol to keep up the surveillance of the area and show force when needed in Batumigrad/Norrkoping. An important part is to keep a good relationship with the local population. The battalion has the responsibility of an area in the city with a majority of Zack population. The area also includes some areas with Bowl majorities. The patrolling will be both by foot and by vehicle. For the surveillance it is possible to put up some sensor systems in important areas.

		The platoon takes a defending position in the street at the exit of the campus. The company responsible for the area in which the campus is situated tries to contain the situation by isolating the campus and controlling the line of separation between the Bowl and Zach areas. However, this is difficult because Zack people want to enter the campus through the Bowl area to take control over the Campus. (Vignette 2, situation 2 and 3) BOWL Batumi Freedom Fighters (BFF) are located in a building near the campus The battalion is trying to first isolate and perhaps as a second step take control over the building with the purpose to deny the entry of these BFF fighters and is observing the campus area. (Vignette 2, situation 1)		
Subject of interest and events that might occur	1) Check of main road ahead of convoy and check of alternative roads. 2) The main route is blocked by a crash between two trucks. It is unclear if this blockade/crash is set on purpose. 3) A vehicle of own troops is involved in a traffic incident. Three soldiers are injured and two Zack people are killed. The Zack population is starting to revolt against the NATO troops.	1) Take position to isolate and to possibly take control over the BFF controlled house. (Vignette 2, situation 1) 2) Get an overview of the crowed in the Riot and which way they are heading before they pass the line of separation and enter the Bowl area. (Vignette 2, situation 2 and 3) 3) The student counselor is arriving at the NATO troops outside of the campus and would like to enter the campus in order to get a grip on	1) ZLF and ACS deserters have concentrated their forces and are conducting an ambush of the NATO forces and they destroyed two CEV vehicles and pinned down a CEV platoon. 2) Zack population is blocking the road and are angry against the NATO forces.	1) The main route is blocked by a crash between two trucks. No people can be seen with the trucks? Booby-trap, car bomb or what? 2) Different kinds of mines both against personnel and vehicle. 3) Car bombs along the patrol road. 4) Suicide bombers both mixed with people and people who try to come in to our camp etc.

		the situation. It is unclear if he will be able to deescalate the situation. 4) The ZLF breaks through the blocking position of one of the platoons of the NATO forces and enters the campus area, heading for the BFF occupied building.		
Decision making				
The tasks the battalion will perform:	• Explore main and alternative routes using UAVs. • Conduct surveillance operations in BG AOR by The Sense company. • Drive and take positions by a company and vehicles in order to keep the route open and manage traffic. • Take position to keep route open by platoon after crossing the main intersection. • Occupy key AOR areas. • Establish observation posts (and possible checkpoints) and conduct patrols after entering and taking control of the district. [Note: The population is not favoring the NATO forces, however, large threats are not expected.]	• Conduct surveillance operations by The Sense company in the BG AOR. • Conduct patrols, including the campus, in the AOR by a company. • Conduct patrols in their AOR by the two companies and provide an additional reserve of a half platoon if necessary. • Perform guard duties of the base and ACS weapon storage sites by the second company.	• Conduct surveillance operations in the BG AOR. • Prepare to retake the block by two companies. • Secure the area by two companies to prevent Zack ZLF reinforcements coming in and escaping of ZACK ZLF armed people.	• Explore the patrol and alternative routes using UAVs. • Assign security level for road patrolling. (Different levels in different areas? What are the indications for the choice?) • Perform foot-patrolling in different areas. (Number of soldiers? Support?) • Who takes decision of how to handle road blocks?

Information needed to set up this plan:	• The required speed of deployment. • Implication on number of routes used to arrive in the AOR. • The threat. Is the population against it and how likely are barricades to be set on the main route? This influences the number of and alternative routes, the use of weapons and the intensity of checkpoints. • The condition of the roads and possible choke points. • Geographical information to determine suitable locations for observation posts. (Where do roads cross?) • Population activities. For example, will there be an open market or are all people indoors? Where are Zack factions located and how will they act? This influences the segmentation of the area and the routes of the NATO forces to deploy first. • What are possible situations the observation posts or patrols might be challenged with? Humanitarian situation, people begging for food? Threats and attacks?		• Where are ZLF battle positions located and how many heavy weapons have they seized? • Are BFF personnel involved in seizing the weapon storage site and have they seized heavy weapons. • Will BFF personnel get involved in the crises?	• The number of routes the units will use to patrol in the area. • The threat. Is the population against it and how likely are barricades on the main route? • The condition of the roads and possible choke points. • Geographical information to determine suitable locations for ambush in areas of hostile groups. • Activities of the population. For example, will there be some bigger events that make many people gather? Might the events turn in to something threatening? • What are possible situations the patrols might be challenged with? Humanitarian situation, people begging for food. Threats and attacks? Ambush? Mines?

Commanding Information requirements during conduct of the plan, since this information was not certain at the decision making phase (thus should be verified) or might be dynamic (rapidly changing).	Battalion level: • Progress of deployment of companies. • Reaction of the population. *Company level (the company responsible of the AOR security):* • *Progress of deployment of platoons. The platoon that should take positions at the harbor bridge and the two platoons that establish observation posts and conduct patrols in the area. Which soldiers are at what observation post and what is the situation? Reaction of the population.* • *The ability to use roads. Are roads blocked and are roads passable for heavy equipments?* Platoon and group level (the platoon that is securing the three bridges): • Progress on creating the position on the intersection by the three groups. • Possible threats in the near neighborhood of the intersection. Are there buildings in the neighborhood that overlook the intersection?	Battalion level: • Progress of redeployment of companies. • Reaction of the Zack and BOWL population. • Activities of the Batumi Police. *Company level (the company that is taking care of the security of the campus):* • *Progress of deployment of platoons. Can the area of the campus effectively be isolated? Which soldiers are at what observation post and what is the situation.* • *Reaction of the population.* • *The ability to use roads towards the campus. Are roads blocked and are roads passable for heavy equipment.* • *The ability to reach, isolate and take control over the BFF building.* Platoon and group level (the QRF platoon that is securing the approaches to the campus): • Progress on creating checkpoints on the approaches by the three groups.	Battalion level: • Progress of deployment of companies. • Reaction of the BOWL and ZACK population. • Activities of the Batumi Police Force. • Location and activity of the brigade reserve. *Company level (the company that is taking care of the security of the area):* • *Progress of redeployment of platoons. Can the building be effectively isolated.* • *Can the building be approached without being detected.* • *Reaction of the population.* • *The ability to use roads. Are roads blocked and are roads passable for heavy equipment.* Platoon and group level (the CEV platoon that is assaulting the building): • Progress on the approach to the building by the three groups. • Location of the enemy heavy equipment.	Battalion level: • Planning of patrolling by vehicle and by foot in a non regular schedule. • Which patrol is at what location and what is the situation? Reaction of the population? • Which mobile sensor (UAV) can quickly support which patrol with information if in trouble? *Company level (the company responsible for AOR security):* • *The ability to use roads. Are roads blocked and are roads passable for heavy equipments.* Platoon and group level: • Possible threats in the near area of the patrols. • Which soldier is in which patrol.

	• When new troops will arrive and pass the bridge. The extent of traffic.	• Possible locations of snipers in the neighborhood that overview the checkpoints, and the BFF building? • Are there buildings in the neighborhood that overview the intersection, line of separation and the roads leading up to it.? • Can the BFF-building be approached by us without being detected?	• Strength of opposing forces. • Are there possible hostages or non-combatants inside of the building? • The time new troops will arrive and pass the bridge. The extent of traffic.	
Additional information requirement at:	Event 1 (Blockade on the main route): Battalion level: • The expected duration of the blockade and the progress of own forces in passing this intersection. To determine if the clearance of another route is necessary. • What is the possibility of escalation of the incident? To determine if the other unit should be tasked to deescalate and to determine guidelines for the company. Company level: • Is the situation a set up or a coincidence? If the situation is set up, what are the underlying grounds.	Event 1 (Breaching the defence perimeter): Battalion level: • The exact location of the penetration of the defence perimeter? • Are Zack combatants and non-combatants mixed up? • What is the possibility of escalation of the incident? To determine if the other unit should be tasked to deescalate and to determine guidelines for the company. • Possibility for cooperation with the Batumi Police Force. • Is the route between the campus and the battle group base still open for casevac (evacuation of casualties)?		Ambush (Mines): Battalion level: • The exact location of the ambush site. • Can the ambush site be isolated. • Is the brigade reserve able to free the ambushed platoon. • What is the situation at the ambush site. • Is the route between the ambush site and the BG Base still open for casevac. Company level: (Brigade reserve) • Is the situation a set up or a coincidence? If the situation is set up, what are the underlying grounds?

- Number of vehicles that are involved in the incident.
- Number of people involved in the situation.

Platoon and group level:

- Is the situation a set up or a coincidence? If the situation is set up, what are the underlying grounds.
- Who is responsible for dealing with a traffic accident? The local police (BPP) or not? What are the ROE in this case?
- Background (ethnic, member of a faction) of people involved in the situation.

Company level:

- Is the situation set up or a coincidence? If the situation is set up, what are the underlying grounds?
- Number of vehicles that are involved in the incident.
- Number of people involved in the situation.

Platoon and group level:

- Is the situation a set up or a coincidence? If the situation is set up, what are the underlying grounds.
- Who is responsible for dealing with Riot control? The local police (BPF) or not? What are the ROE in this case? Are they able to deal with this problem?
- Background (ethnic, member of a faction) of people involved in the situation.

- Number of weapons and people involved in the ambush.
- Number of people involved in situation.
- Number of casualties to be evacuated.
- Platoon and group level: (Brigade reserve).
- What are the ROEs in this case?
- What is the exact location of the ambush?
- Background (ethnic, member of a faction).

Some acronyms used

AOR	Area of Responsibility	ACS	Alliance of Caucasus States	BG	Battle Group
BFF	Batumi Freedoms Fighter	BPF	Batumi Police Force	casevac	Evacuation of casualties
QRF	Quick Reaction Force	ROE	Roles of Engagement	UAV	Unmanned Aerial Vehicle
ZLF	Zach Loyalist Forces				

Annex C – IST-046 WAR GAMING RESULTS

TNO Fysisch en Elektronisch Laboratorium

Memorandum

Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek / Netherlands Organisation for Applied Scientific Research

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Datum
21 mei 2004

Onze referentie

Doorkiesnummer
40161

Results of IST-46 Meeting 22-26 March 2004, The Hague

This memo composes of two parts:

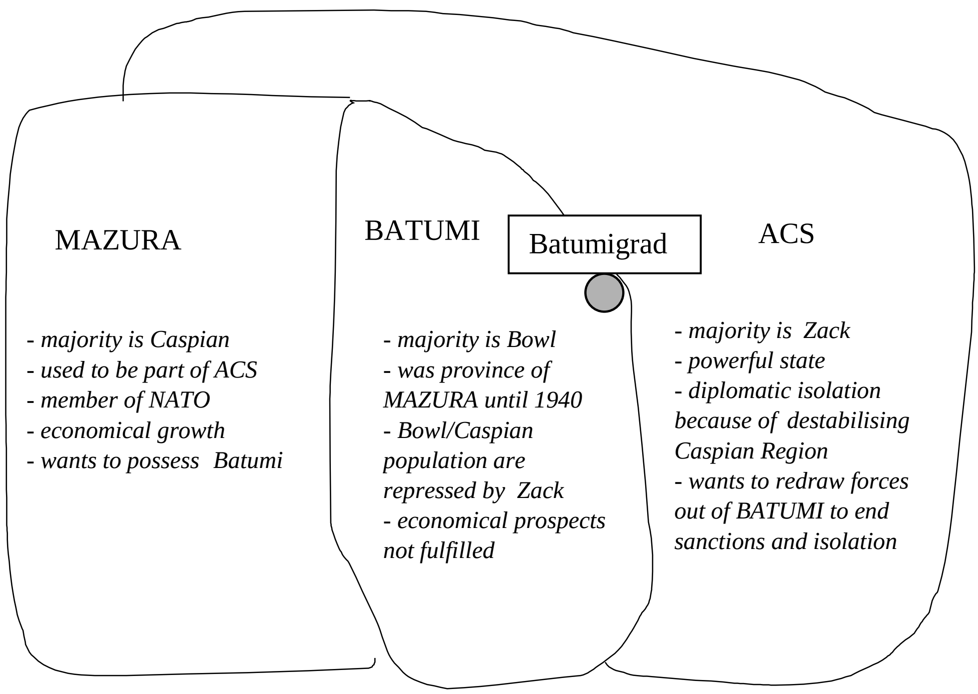
A. Updated Vignets

B. Clustered Information Requirements (see also the Excel sheets)

A. Updated Vignets

1. Context

Tensions exist in BATUMI which is the province of the Alliance of Caucasus States (ACS). ACS and neighbor state MAZURA both want to control BATUMI for years. ACS has invaded the South of MAZURA in 2015. NATO forces defeated this attack. After elections in 2024 in ACS moderates replaced the radical party. They agreed to conduct a phased withdrawal of the ACS forces out of BATUMI. In exchange for this the ACS leadership wanted to secure monetary loans, make a goodwill gesture to the UN and international community and they hoped that the Bowl groups would stop with terrorist attacks etc. The ACS forces would withdraw and NATO forces would replace the ACS forces in BATUMI. Forces of MAZURE would stay out of BATUMI. However not all Zack people did support this idea and a lot of Zack people deserted the ACS forces.



The following parties are involved in the capital Batumigrad:

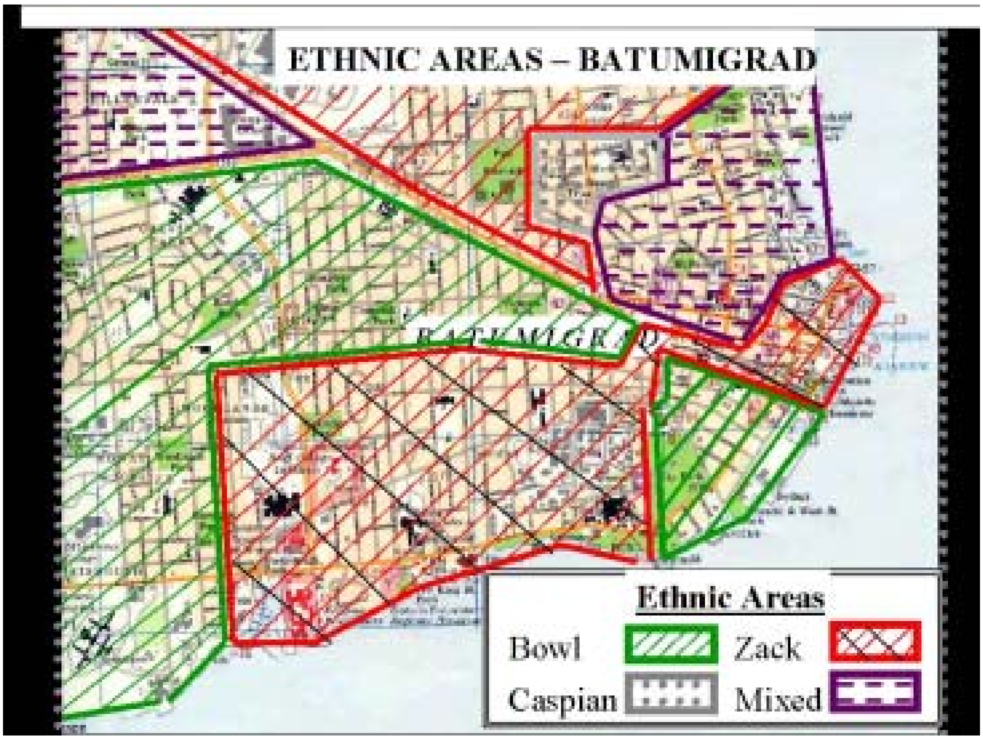
Etnic groups:

	BOWL		ZACK		
Political	**BDP** Some members support BLB		**ZLP** Link with ZLF		
Military	**BLB** Moderate 100 pers	**BFF** Radical 100 pers	**ZLF** branch of ZLP company-size	**ACS Zack deserters** Deserters of ACS forces some hundreds	**ACS forces** Some forces stayed behind 2 light SF companies

Other parties:

UNMIB 20 observ.	**IDP** Refugees from the country	**BPP** Police Initial 200 people Zack policemen deserted Mix of etnic groups

BDP:	Bowl Democratic Party
BLB:	Batumi Liberation Brigade
BFF:	Batumi Freedom Fighters
ZLP:	Zack Loyalist Party
ZLF:	Zack Loyalist Forces
UNMIB:	UN Mission in BATUMI
IDP:	Internal Displaced Persons
BPP:	Batumi Provincial Police

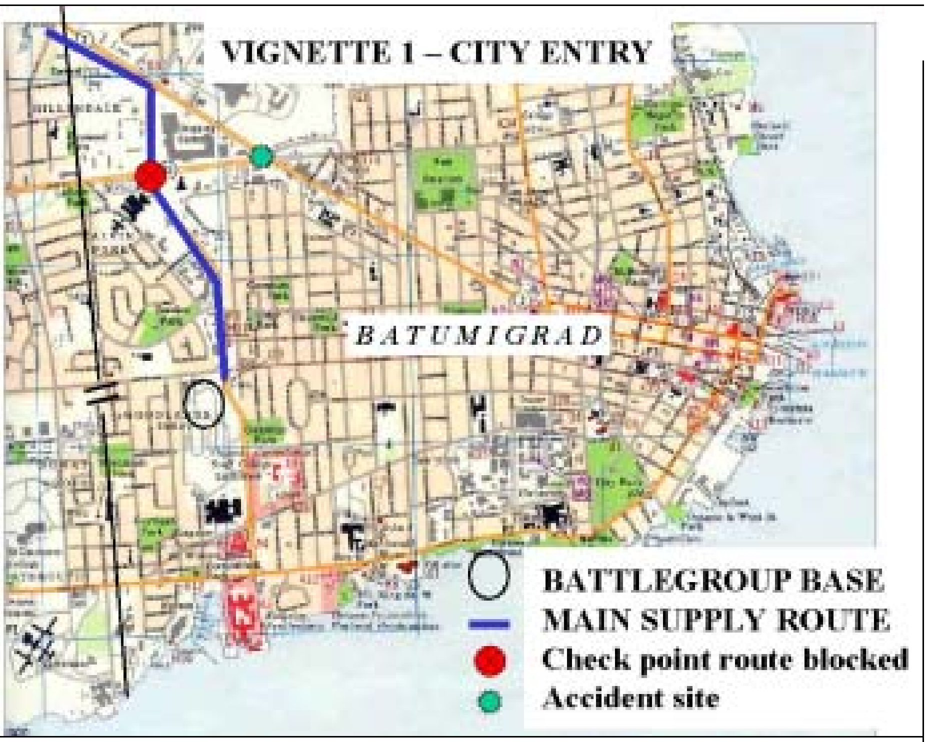

ETHNIC AREAS – BATUMIGRAD
BATUMIGRAD
Ethnic Areas
Bowl
Zack
Caspian
Mixed

Vignette 1: Deployment of battalion in Batumigrad without large opposed threats
(Crisis Response Operations)

In this vignette the battalion will set up a compound for the battalion in Batumigrad. The battalion has the responsibility of an area in the city with a majority of Zack population. The building for the compound is already chosen and inspected. First a provisional battalion command post will be created.

The battalion exists of 4 companies:
- 3 Close Effect Vehicle (CEV) companies and (A-, B- and C-Coy).
- 1 Multi Mission Effect Vehicle (MMEV) company.

The first CEV company will take care of the Line Of Communication (LOC). The second and third CEV company will patrol the battlegroup AOR. The MMEV company will take care of the security in the area around the compound, will organize the situation at the compound and a part of it is battlegroup reserve.

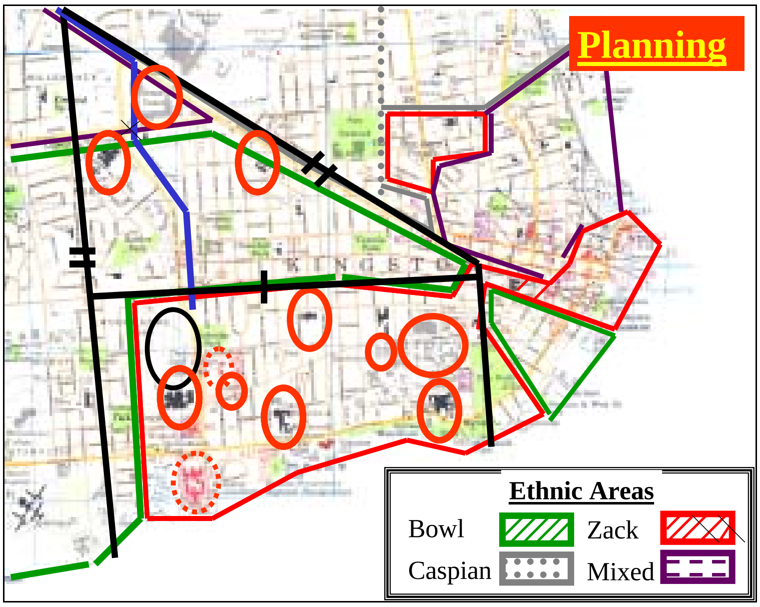


Tasks of battalion:
- Disarmament of armed factions in BATUMIGRAD within boundaries.
- Provide a secure environment for ZACK, BOWL and CASPIAN communities within boundaries.
- Create the conditions for the orderly return of IDPs.
- Secure key city utilities and critical infrastructure.
- Secure the Batumigrad Provincial Legislative Building and Provincial Court House.
- Secure key cultural sites within AO.
- Secure city schools located within areas of real, perceived or potential ethnic tension:

- Secure the Batumi Aluminium Plant, the Batumi Centre Business Park complex and other assessed commercial areas of importance.
- Provide emergency humanitarian assistance, as necessary, within boundaries.
- Assist government and NGOs/humanitarian agencies within boundaries.
- Assist in promoting UNMIB mission within boundaries.

Mission: Restore order in AO.
Intent: Rapidly win the confidence and respect of the local population the AO through presence, professionalism end transparency of cause.
Scheme of manoeuvre: Occupy AO with two CEV coys responsible for a major faction area and a third for QRF and special tasks, i.e. NGO support as required. The MMEV coy will secure the camp and act as reserve. Establish robust sense org based on humint and imint. **Main Effort**: Establishing rapport with all local factions.
End State: Freedom of movement and fear amongst the people of Batumigrad in my AO.

Assumptions:
- Highway 2 in my AO (the accident site is my responsibility).
- The units on my flank are from my brigade.



Figuur 1: AOR's of battalion and of the two CEV companies that will patrol the area, and important buildings.

Events that might occur in this vignette are:
- The main route is blocked by a crash between two trucks. It is unclear if this blockade is on purpose.
- A vehicle of own troops is involved in a traffic incident. Three soldiers are injured and two Zack people are killed. The Zack population is starting to revolt against the NATO troops.

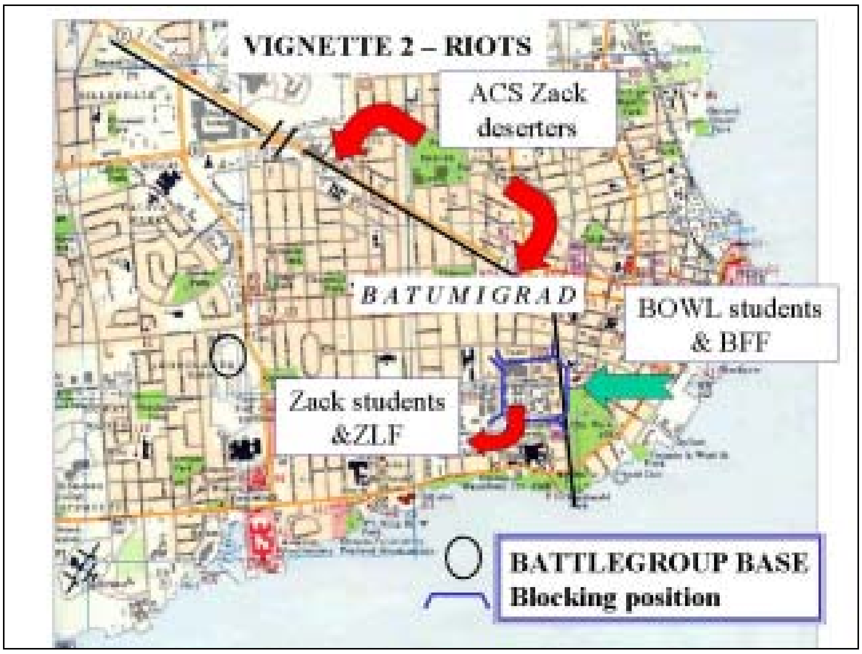
Vignette 2: Riots at the university main campus and an attempt of Zack factions to expand their control over important Batumigrad sites.
(Defensive operation)

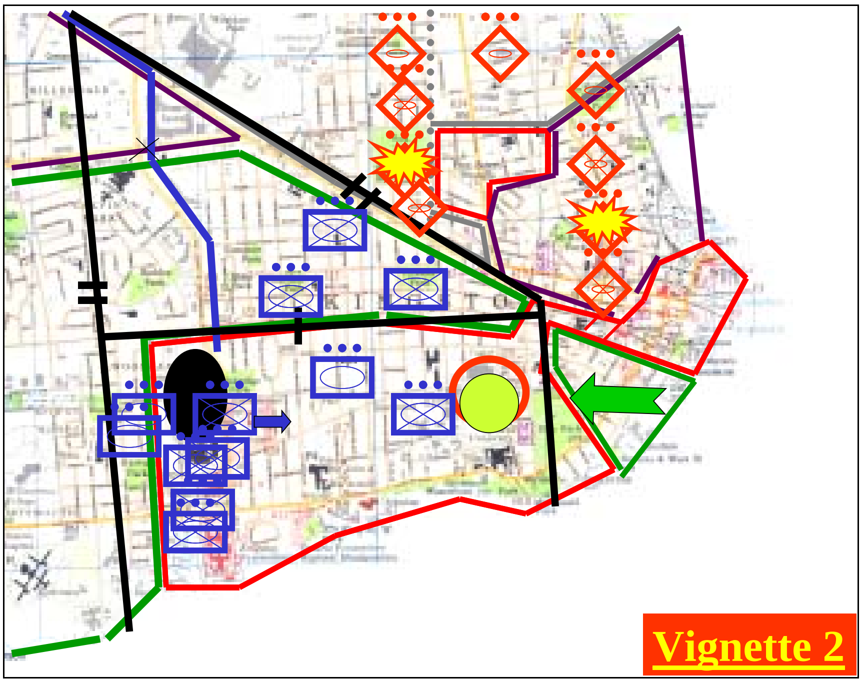
The battlegroup commander is on speaking term with the leader of ZLP Mrs. Maria Cliver. The Batumi Police Force is active and cooperating with NATO forces. The Batumigrad police can muster a platoon for crowd and riot control. However policemen receive only a small pay and can not completely trusted to be impartial.

After a week of riots at the university campus the intensity of the riots were enlarged by the assassination of a high ZLP official. The ZLF are shooting Bowl students at the campus. The heavy weapons of the ACS deserters are stored at a NATO controlled site, however a large amount of manportable weapons are still available to ZLF and ACS deserters. The QRF platoon of the battalion has detected this shooting and reports that some hundreds of people are involved in this incident. Civilian casualties are being evacuated in civilian ambulances. The international press provides live TV pictures of the event. The platoon takes a defending position in the street at the exit of the campus. The company responsible for the area in which the campus is situated tries to contain the situation by isolating the campus.

However this is hard because Bowl people want to enter the campus to take revenge on the Zack people and Zack people want to exit the campus. BOWL BFF fighters are located in buildings in the close neighborhood of the campus that is outside of the AOR of the battalion. The battalion is trying to deny the entry of these BFF fighters and is observing the Battlegroup border area.

Next to this escalation between Zack and Bowl people, the ZLF and ACS deserters take advantage of the situation by creating chaos and trying to expand their control over important Batumigrad sites.





One company (A coy, north) has got the task to defend the AOR against an attack raised by the ACS deserters.
One company (B coy, south) has got the task to contain the university area and making sure that the Bowl students and BFF are not able to interfere with the problem at the university area.

Scheme of manoeuvre:
Situation in the northern part of the AO.

- Two blue platoons are operating together in A Coy AO. Local Authorities and Local Leaders are contacted. Through media ops local population are notified that Blue movements are precautionary. As Red Forces begin to advance (2 hours later), two platoons of A Coy will take in hasty defensive positions. The third platoon is in support. Defensive positions are taken up based on predicted Red Avenues. The MMEV Coy and C Coy at the compound anticipate movement. C Coy supports A Coy with 2 platoons.
- Zack advances to highway 2 (border of sector). Two MMEV platoons are attached to A Coy. At the same time, the MMEV Coy commander moves with a third A Coy platoon to Legislative Building to support the existing MMEV platoon at the Legislative Building. The battalion commander moves to this building. As the battalion commander leaves the Base, the Zack Special forces fires into the Base. The battalion commander takes much longer to get to the Legislative Building due to pot shots from Special Forces.
- Two platoons are involved in battles on Route 2. Red counter moves to west, still within adjacent sectors AO. Blue is requesting Air Support for units moving west. A Coy depth platoon is countering the move to the west behind Route 2. And associated MMEV platoon moves to the most probable Red Avenue of Approach.
- The Battalion needs to cross Route 2 into adjacent sector in pursuit of the red units. Coordination is needed with adjacent battalion. During the consolidation the

battalion quickly reestablishing pre-event activities and resupplies critically low, followed by not critically stocks.

Situation in the southern part of the AO.

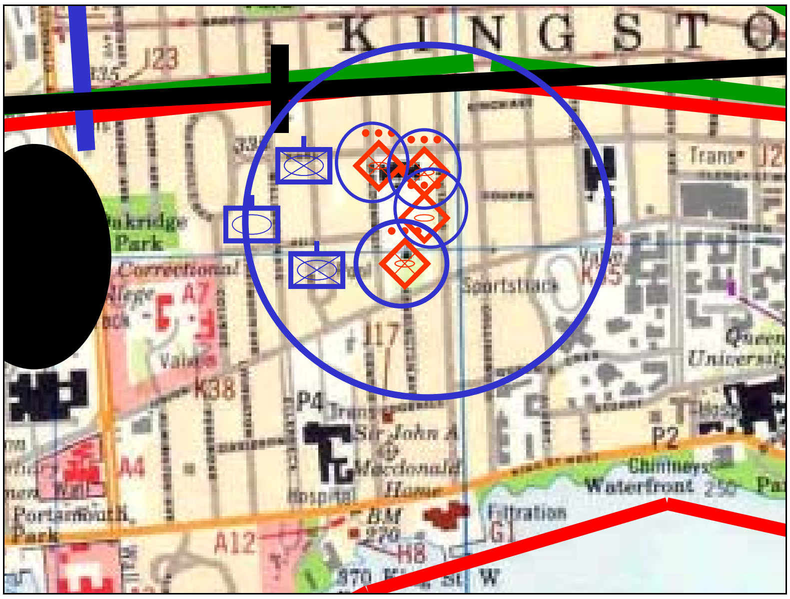
- Red Forces initiate riot at University. Rioters move to contact with NATO forces. The police is notified for support. B Coy has two platoons close and is coordinating with the police. They request CAS in order to show the force. C Coy supports B Coy with one platoon.
- After the rioters have been dispersed the B Coy becomes Depth support for A Coy. However their task remains to maintain visibility on dispersing crowd.

Events that might occur in this vignette are:

- The student counselor is arriving at the NATO troops outside of the campus and would like to enter the campus in order to get grip on the situation. It is unclear if he will be able to deescalate the situation.
- The ZLF breaks through the blocking position of one of the platoons of the NATO forces and enters the university terrain.

<u>Vignette 3: NATO forces should regain the area controlled by ZLF and ACS deserters.</u>
(Offensive operation)

After the riots the ZLF and ACS deserters have seized the Provincial Legislative Building and they now control downtown core and approaches to it. Additional street barricades and the presence of small crowds of angry Zack civilians are present. The BFF and BLB are attacking the Zack civilians and cultural sites. An unknown faction has seized a weapon storage site and heavy weapons are under their control. The battalion has to regain the control of this area to create a stable situation again. The ZLF and ACS deserters have prepared barricades and are present at all corners of the two main streets in the downtown area. They might also be present in and at the top of buildings. The battalion will try to isolate the area and expand control.



The battalion will regain the control of the Provincial Legislative Building by first attacking the enemy armored element by helicopters. Than the MMEV company will attack the armored platoon with direct fire. The CEV company (B Coy) south will then clear the buildings in the south. These buildings do not have to be preserved, however it is unclear yet if there are hostages inside. While the CEV company south is entering they have to be sure that the tankplatoon is killed and they might be fired at from the northern buildings, so they need cover. The CEV company (A Coy) in the north will only enter if the southern buildings are cleared, and they have to clear several buildings that are not allowed to be damaged.

Scheme of manoeuvre:

- The battalion creates a psyop plan in order to deal with the media. In coordination with the police the traffic is managed and the area is cordoned off. The area is cleared of civilians. The battalion commander chooses to initiate the action at dusk. Once the underground passages are learned, Blue blocking positions are set up. The blocking positions are done by the Recce platoon and one platoon of C Coy. The battalion commander is on site. The location of the enemy is done by the MMEVs in support by fire locations. Aviation support will be requested for.
- Red is notifying CNN while Blue is clearing adjacent houses. Blue wants to block telephone cell coverage out of the building, including satellite phones and other communication systems. Zack sympathizers move to outside of the building. Everything is now on CNN.
- After perimeter established snipers are deployed. An attempt is made to contact the Zack leader. As soon as Red Leader denies negotiating, sniper fires taking out several Zack soldiers.
- After a second phone call with the Red leader and a rebuff, the MMEVs move into position to fire on the Zack tanks. Urban environment negates the range advantages of the Blue over Red, therefore ranges are equal. Therefore the MMEVs depending on Non-LOS assets. Aviation engages a few visible targets, inside building taking out one dead tank, two immobile but can fire. One helicopter shot down. Zack crowd disperses. After the Apache went down, the C Coy in reserve is given the mission to secure the downed Apache. C Coy coordinates MEDEVAC.
- In the third phone call Blue offers surrender. Red denies Zack authorities, game still on... No free passage, arrest is offered. B Coy is taking the southern building while suppression is taken care of by A Coy. Blue now owns everything except for the Legislative building. A few Red dismounts are left in side buildings. Snipers engageing all visible targets.
- In the fourth phone call Red wants to negotiate with international presence. Negotiatings break down. A Coy is deployed to clear the northern building. Red fights and attempts to break off and escape.

Events that might occur in this vignette are:

- ZLF and ACS deserters have concentrated their forces and conduct an ambush at the NATO forces and they destroyed two CEV vehicles and pinned down a Cev platoon.
- Zack population are blocking the road and are angry against the NATO forces.

B. Clustered Information Requirements

In this part the results of the The Hague meeting (22-26 March 2004) are listed (see also the Excel file). The information requirements the group has produced has been organized in clusters afterwards by TNO. An explanation of the clusters is described below.

Five types of information are distinguished:

- Static physical: Information on the static physical elements of the operational environment. Static elements have got a fixed location on the map and are not able to move. Physical elements are made of some material and therefore visible and tangible. Examples are buildings, underground constructions and infrastructure.
- Dynamic physical: Information on the dynamic physical elements of the operational environment. Dynamic elements are able to change of location. This can be done by themselves (people) or by help of people (cars, trains, explosives). This category only describes the physical information on these dynamic elements; the visible and tangible information. For example location, number, equipment and activities of people.
- Mental: Information on the mental elements of the operational environment. Mental elements are not visible but are hidden in the minds of people. The activities of people might be an indicator for the intentions and feelings of people.
- Enhanced data: Enhanced information on the operational environment derived from the static physical, dynamic physical and mental data. This enhanced data combines the former information categories in order to get more insight in the operational circumstances. For example information on battlefield effects (detection ranges, weapon coverage, speed, avenue of approaches, route planning) but also how to influence the enemy and population with mediaops.
- Command and Control: Information that flows between unit levels and between other (neutral) parties in order to execute the decision made by the commander based on the first four information categories. This information category composes of orders, requests, information updates (upwards or downwards) and coordination with other units or (neutral) parties).

The type of information influences the collection, distribution, processing and representation methods for the information. Mental information is hard to collect with robots and physical information on the city is hard to describe in words. Besides the type of information the required speed of information is crucial for the methods to be chosen. The more time is available the more in-depth and time-consuming the method can be. The less time is available the more the methods should be focusing on the most relevant information and make sure that the information is distributed to the relevant persons at the needed speed. Two categories have been formulated:

- Long planning time: The information in this category is not needed within the hour, but is gathered and analysed over days, weeks and even longer in order to supply the commander with the necessary information to come to a decision on the course of action for a certain mission (often in the preparation phase).
- Short planning time: The information in this category is needed within a few hours, often preferred near real time. This information is needed during the execution of the mission in order to supply the commander and the units with the

necessary information to monitor the situation and react on the circumstances in time.

Information Requirements	Static Physical	Dynamic Physical	Mental	Enhanced data	Command & Control
Long Planning Time	Mapping of the city (above and underground) Identification of key sites (hospitals, utilities, schools, government buildings etc.)	Generic information on location and capabilities of factions Locations that are high risk for the mission (eg might become a threat or an obstacle)	Culture of the country / region Determine enemy intent and objectives Knowledge of intent/opinion other parties (incl population, NGO, international opinion)	Trend information by fusing pictures.	Long term communications with factions. Long term communications with Police, NGO, Population representatives Determine plan for stabilisation of the region including force protection and sustainment Establish command and control structure
Short Planning Time	Mapping of specific parts of AO Information on utilities Locations of local services	Enemy position and activity during specific action or event Own forces positions (including local police) and activities during specific action or event Information on dynamic obstacles (incl crowds) during specific action or event	Determine enemy intent and objectives in the specific situation Knowledge of intent/opinion other parties in the specific situation (incl population, media)	Path planning during operation / movement Prediction of enemy actions Analysis of capability performance in urban enviroment (coverage, COA)	Coordination of PsyOps campaign in the light of current events Coordination with adjacent units, police and NGO's Communication with factions/etnic groups Requests for ROE Requests for deployment of higher level assets Reports on current situation

Long Planning Time - Static Physical

BAT

1. Determine location of key city utilities
2. Determine location of key cultural sites
3. Determine location of key city schools
4. Determine location of Legislative Building and Court House
5. Determine location of AL plant and Centre Business Park
6. Information on possible ROTA locations
7. Require detailed route network within AO
8. Need communications coverage in AO
    - Dead spots that restrict operations should be augmented by placement of relays (ground/building/aerial)
9. Control traffic lights
    - and other civil infrastructure
    - control cell phone networks
    - shut down power if necessary
10. Need Blue Aves of Approach
    - Maximize mobility
11. Need possible Red Aves of Approach
    - What are predicted avenues
    - Possible speed of advance
    - Predicted movement over time
    - Weapons range fans
12. Need 3D and subterranean model of city
13. Mapping of building
    - Need buiding maps
    - Need subterranean routes in for blue forces
    - Need subterranean routes out for red forces
    - Need subterranean maps in vicinity
14. Overlay of the sewersystem (other onderground routes) on the map

SUMMARY

Mapping of the city (above and underground)
- Including all kind of infrastructure (phone networks, sewersystem etc.)
- Including routes
- communications dead spots

Identification of key sites (hospitals, utilities, schools, government buildings etc.)
- mapping of key-sites / buildings
- ROTA overlay of the city
- heli-landing sites

Short Planning Time - Static Physical

BAT

1. Critical points surrounding event site to isolate
2. Identify alternate routes and assist rerouting of traffic
3. Mapping of building
   - Need buiding maps
   - Need subterranean routes in for blue forces
   - Need subterranean routes out for red forces
   - Need subterranean maps in vicinity
4. Information on red advancing
   - His route is needed
   - He is following Zack lines of control
5. Information on Rioters move to contact w/ NATO forces
   - Need their current ave of advance
6. Information on Contact on Rt 2
   - Need RT overhead imagery over engagement area
   - Need possible new Red Aves of Approach
7. Need Ave of Approach
8. Identify buildings from which Red will defend from
9. Identify buildings that we can defend from
   - Buildable database over time, but now becomes punctual
10. Information needed for Consolidation
    - Routes for returning to pre-event locations
    - Need resupply MSR routes planned
11. Information on utilities
    - Manage power in building
    - Manage water
12. Locations of local services
    - Police, local government

COY/PLT

1. Request for a three-dimension map of the building (INFRASTRUCTURE: including stairs, windows, underground and all possible details and SERVICES: electricity, gaz, water supply) - the viewing must be as realistic as possible and "change detection"-oriented
   - Moreover: air-conditioning network -- for NLW (gaz) use purpose
2. Request for information on non-firing zone inside the building (national archives ?)
3. Complete set of maps of the campus and its immediate vicinity
   - Rooms (of sufficient size to temporarily hold people), cafeteria, roofs (access and elevation)
   - Underground passages (steam conduits, pedestrian tunnels, storm drainage etc.)
   - Entry and exit points to buildings, gates
   - Location of chemistry and physics labs
   - ROTA: petrol and power stations
   - Medical facilities
   - Surveillance systems
   - Telephone hubs
   - Exterior lighting system
   - Including the heights of the buildings (to determine the positions for the own troops)
   - Suitable rooms for possible temporary detentions of students.
   - Information is needed on light infrastructure (to know what areas will be lighted and how to cut off parts of the lighting if needed)
4. Obtain status of vehicle destruction operation
   - Time of completion
   - Presence and state of wounded, friend or foe
   - location and state of destroyed vehicles
5. Obtain plans or indications about the houses
   - Rooms
   - Entrances
   - Blueprint of every level of the house
   - Tunnels leading to the house
   - Possible storage of WMD, toxic material, weapons
   - Use of boobytraps?
   - Information on the construction blueprints; composition of outer and inner walls. Type of roof (slope, material, presence of knee-wall), type of windows.
6. Need reception of updated picture (could be a map, an enhanced image, etc) of the current situation - area of interest - near real time)
7. Need reception of visible warning (immediate action - real time) for ACTIONS/EVENTS that can influence the execution of the mission (e.g. blockades, firing, grouping of population, riots, accidents)
8. Terrain Report of possible location of threats + difficult access, ... (surrounding of camp)
9. Request information in a large area (perimeter) around the scene to discriminate the event
10. Request a local survey of the zone of interest (accident)
11. Obstacles like manholes, mines, explosives etc.
    - The assumption is is that the platooncommander has received instructions how to react on obstacles (recce or alternative route)
    - Picture ahead of the route

Static and dynamical obsticals
12. Possible threats from the buildings.
From inside the building
From the top of the roofs
Underground complexes
13. 360 degree coverage from the vehicles

SUMMARY

Mapping of specific parts of AO
obstacles / road blocks (static & dynamic)
event overlay
buildings
above and undergound
Information on Utilities
Control infrastructure
Locations of local services
Police, local government

Long Planning Time - Dynamic Physical

BAT

1. Information on NBC(wmd) / possible ROTA incidents
2. Determine location of armed factions
3. Determine location of ethnic leaders
4. ELINT (COMMINT)
   Cell phone activities monitored
5. Knowledge on potential flashpoints
6. Imagery from rooftops, towers or on ground UGVs to vary monitoring locations

COY/PLT

1. Require information about the enemy forces
   Require immediate indications (elementary analysis) of enemy communications
   Require information about the nature, volume and location of the enemy forces
   Location: in our AOR but also well outside our AOR. Bn level decides which enemy forces pose a possible threat and filters based on this assessment
   Require information about the effectiveness of the enemy forces
   Offensive capabilities
   Crossing capabilities
   Require information about likely routes/ way of approach the enemy forces may use to enter our AOR
   Times the enemy needs to reach certain positions
   Require continuous surveillance on specific areas (Albert St to Toronto St)
   Require information from remote sensors in, on and under buildings
   Require profile of action of enemy leader
   Require information on exact and real-time location of the enemy leader (for determining intent or also for targeting)
   Enemy communications: translation, blocking, deception, intrusion
   HUMINT, population, partisans
   Require information about enemy fire locations (e.g. sniper detection)

SUMMARY

Generic information on factions
- Locations
- Capabilities

Locations that are high risk for the mission (eg might become a threat or an obstacle)
- ROTA
- Flashpoint areas (eg ethnic borders)
- traffic jams

Short Planning Time - Dynamic Physical

BAT

1. Information on NBC(wmd) / ROTA incidents
2. Need NRT overhead imagery to analyze movement within cities
   - Need real time imagery above entire A Coy AO and adjacent unit
3. Need Blue Force Tracking
   - Need adjacent unit Blue Force tracking in NRT
4. Need Red Force tracking (when known)
   - Tool to track Red forces on overhead image, automatic following
   - Once tagged on overhead image, track!
   - Snipers are tagged and already targeted
5. Need White Force Tracking (especially masses)
6. Logistics information
   - Need automated resupply
7. Monitor Cell Phones
   - Jam their comms
8. Red Forces initiate riot at University (Vignette 2)
   - Detect the riot is occuring
   - The extent of the rioters
   - Their direction of movement (if any)
   - Need overhead imagery over university
   - Need update of Zack battle during riot
   - Need their current ave of advance
   - Track rioters from overhead and tag buildings where they retreat to
9. Zack advances to highway 2 (border of sector) (Vignette 2)
   - Good Red Force Tracking
   - Need routes from Base to Leg building that are concealed from Red SF taking shots to disrupt
10. Rear Base Security / Counter Red eyes on our Base (Vignette 2)
    - Detection of sniper positions
    - Determine OPs and Fire Points
    - Location of enemy
    - Sensors to trigger SENSE people
    - mortar detection
    - RPG detection
11. Need 3D Blue force tracking (in building) (Vignette 3)
    - COs and PLTs may want floor that soldiers are actually on.
    - Red Force 3D Tracking if possible
    - Particular interest in subterranean routes that may be used
    - 3D "RED" Force tracking in the building and during Red egress of ALL other building occupants
    - For aviation support
12. Overhead Imagery (Vignette 3)
    - Full time live overhead imagery with Thermal
    - Red vehicles hidden under overhead cover (houses/trees)
    - Fires lit to confuse thermal sensors
    - Require persistent overhead picture (i.e. from rotary wing)
    - Provide overhead imagery and surrounding area movement
    - Neighboring street activities (i.e. movement of masses toward scene)
13. Location of commander (meeting w/ local leaders, establishing repport)
14. Indication of movements (SA through UGS)
    - Underground
    - Ground (tripwires to indicate movement)

COY/PLT

1. Require BDA on past fights
2. Information on the medical status of shot Bowl students, for evacuation or disposal purposes (Vignette 2)
3. Number of students and professors likely to be on campus that day (Vignette 2)
   Can the professors be called in to qualm the rebellion?
   Where are the students (specifically the ones with weapons) on the campus; in what buildings and rooms.
   Recent situation on the roofs of the buildings on the campus as well as the buildings in the near surroundings of the campus
4. How many weapons and type of weapons are inside the campus (Vignette 2)
5. If it is night: information is needed on the possibility of night vision equipment of the Zack students/ZL. (Vignette 2)
6. Status of university administrators and professors over students
   Including pictures
7. Information on possible movement on other ethnic groups in the AO of A-coy
   (since the Bowl people of the AO of A-coy might also come to the campus)
8. Where are the ZLF and the BFF leaders? Are they in the vicinity and can they be contacted?
9. ZLF breaking out. (Vignette 2, event 2)
   Are they carrying weapons?
   Will they get in contact with Bowl people (bowl students or BFF)? The A-coy should avoid this.
   What direction are they headed?
10. Information on the people (red and white) in the houses? (Vignette 3)
    Location and equipment of individual enemies (specifically where is their leader?)
    Number of enemy in the four houses (in the south). Where is the main enemy focus (in what house most of the enemy is)?
    Are there non-combatants in the houses?
    Are the opposing forces wearing explosives on their bodies?
    People being held hostage? Request for SF.
11. For the blue forces outside of the building, blue force tracking of the people inside the building is needed.
    (for possible fire support from outside)
12. Need reception of updated picture
    (could be a map, an enhanced image, etc) of the current situation - area of interest - near real time)
    BLUE position and state
    RED position, state, intent, etc.
    BROWN info.
    Also info about YELLOW (unknown)
    Remark: own company forces and all allied forces within our area of interest (physical)
    Position of neighbouring forces
    Interest is wider than AO
13. Visible warning (immediate action - real time) for actions/events that can influence the execution of the mission
    (e.g. blockades, firing, grouping of population, riots, accidents)
14. Position of media and their obediance
15. Update status of own troops - company - as required
16. Information about ethnic leaders, communities, persons of influence, ... -- around/surrounding of the camp
17. Terrain report of possible location of threats + difficult access, ... (surrounding of camp)
18. Information about the event - road accident blocking the road (nature, volume, attitude, intent of crowd
    gathered in the area of the accident, civil or military, ethnicity, casualties, nature of load, assessment of the situation)
19. Status of injuries and the scope of damages
    Request remote triage
20. Assessment on the situation e.g. on psychology and ethnicity of locals i.e. crowd gathered at the accident

    Request from platoon leader to gather information /detect emerging leaders and personnalities within the crowd
21. Need to see through the walls for enemy positions
22. Information about the enemy forces
    Require immediate indications (elementary analysis) of enemy communications

    Require information about likely routes/ way of approach the enemy forces may use to enter our AOR
    Times the enemy needs to reach certain positions
    Enemy communications: translation, blocking, deception, intrusion
    Require information about enemy fire locations (e.g. sniper detection)

22\. Require time sensitive targeting (targets of opportunity, moving targets)

23. Dynamic alert (change detection including human-motion detection)
24. A "foe" discrimination system - individual soldier - inside building
25. To know if there is civilian (and where) inside the building
    Are they using cell-phone ? (did they call a 911-like system and are in contact ? where in the building ? what kind of info could they give to us ? etc)
26. Special events scheduled that day
    Unusual events like sportgames at a school in the weekend
27. Obstacles like manholes, mines, explosives etc.
    static and dynamical obsticals
28. Information of moving objects (possible threats) behind the surrounding buildings
    (extending the view of the commander to react more rapidly)
    Area of interest
    Look at something unusual like people carrying weapons, crowds etc
    How do the population react on the scene

29. Information if there are people using the sewersystem or not.
    Overlay of the sewersystem (other onderground routes) on the map
30. 360 degree coverage from the vehicles
31. Information on the location of local police.
    The ability to contact the local police and how long it will take the police to arrive at the checkpoint.
32. To obtain info about trucks and drivers (Vignette 1, event 1)
    T o determine if the accident is planned or accidental.
    The contents of the cargo in the trucks (explosives, toxic etc)
    Can the trucks be removed quickly?
33. Information about the background of the 2 killed Zack people and their vehicle. (Vignette 1, event 2)

    If they are related to, for example, a armed Zack group, it's possible that the ensuing reaction could be severe.
    Information about the number of people (of all ethnic groups) moving to the site.
    The platooncommander will relay the information to his superior and perhaps decide on his own if he should leave the site.

SUMMARY

Information on enemy position and activity during specific action or event
- Current positions of involved factions and leaders
- Snipers, mortars, RPG's
- Direction of movement
- Presence of hostages or non-combatants
- Movement underground or in buildings
- Current position on and in buildings.
- Number of weapons and type of weapons
- What factions are involved?
- Enemy communication

Information on own forces positions and activity during specific action or event
- Logistics information
- Medical status
- Position in buildings (what floor)
- Position of commander
- Location of police that might be called for.

Information on dynamic obstacles during specific action or event
- Crowds; grouping of population
- Cars
- Movements of population
- Blockades, accidents, riots
- Position of the media
- Special events that causes grouping of population

Long Planning Time - Mental

BAT

1. HUMINT
    Information on the factions and situation of the population
2. Understand culture and establish rapport w/ local population
3. Determine enemy (Zack deserters) intent
4. Determine tactical objective of Zach forces:
    Their objective is to occupy the govt building
    What is their objective in our AO?
5. PSYOP Plan
    What is the international opinion?
6. Need enemy intent (INTEL)
    International support?
    Request Intel support for intent
    What are other ASC activities?
7. Know NGO plan

SUMMARY

Culture of the country / region
Determine enemy intent and objectives
    Intent
    Skills and tactics of enemy
Knowledge of intent/opinion other parties
    International opinion
    NGO plans
    Local population

Short Planning Time - Mental

BAT

1. Need enemy intent (INTEL)
   - International support?
   - Request Intel support for intent
   - What are other ASC activities?
2. Gather intel from accident scene
   - Language conversion triage if necessary (i.e. documents found in vehicle)

COY/PLT

1. Inform the population to stay at home, report enemy movements
   - Media (radio, TV, loudspeakers)
2. Request for a PSYOPS campaign directed toward the enemies
3. Request for the battalion on the recent contact or possibility of contact of the ZLP leader with ZLF forces on the campus
4. Internal task (REQUEST to platoon) to gather information about ethnic leaders, communities, persons of influence, ... around/surrounding of the camp
5. Request the psychological impact on the population
6. What are the intentions of the Zack students and ZLF at the campus? What do they want?
   - What is causing the riots?
7. What's the current attitude of the Zack students and ZLF towards NATO forces.
   - Are they willing to talk?
   - The same applies to Bowl students
8. Number and actitivites of the TV-crews on or in the vicinity of the campus?
   - What are they broadcasting (are other factions watching tv; for their situational awareness). Probably information needed for higher level than coy-level.
   - Is there someone of a higher level on the spot who is the spokesman with the media?
   - What is the course of action with respect to the TV-crews?
9. ZLF breaking out. (Vignette 2, event 2)
   - What direction are they headed? What is their intent?
10. Assessment of the credibility of a person claiming to be the leader of one of the groups.
11. Information on the people (red and white) in the houses?
    - Rank of enemy combatant
    - Skill level of enemy and known tactics and doctrine

SUMMARY

Determine enemy intent and objectives in the specific situation
- Attitude of factions / neutrals, are they willing to negotiate?
- Credibility of persons
- Rank, skills and tactics of enemy

Knowledge of intent/opinion other parties in the specific situation
- Local population
- International opinion
- Broadcasting of media

Long Planning Time - Enhanced data

BAT

1. Need persistent sensing of area to determine trends over time
   Imagery of critical sites (i.e. cameras for overwatch)
   Detection and localization of Gunshots, Mortars, RPGs, heavy vehicles:
   fused picture presented at CP and results automatically passed to COs as required (i.e. publish/subscribe)

SUMMARY

Trend information by fusing pictures.
Information on capabilities and locations.

Short Planning Time - Enhanced data

BAT

1. Need tool for weapons effects template
   - Must have weapons coverage
   - Must still minimize collateral damage
   - Range effects
2. Need to calculate blast effect for minimizing collatoral damage
3. Automatic path planning updates during movement
   - Path planning fo responding units ingress/egress
   - Optimal routes for medevac
   - covered routes
   - BN CO chooses to initiate action at dusk!
4. Need predicted possible avenue of advance with timelines of enemies or crowds
   - B Coy needs predictive motion of rioters
   - Develop automated COAs

COY/PLT

1. Request a blast analysis (for this particular building) for weapon selection in order to minimize collateral damages
   - Analysis of building vulnerability to assault (fire for instance)
   - Provide route information for Co or QRF (responding unit) to site
2. Request a (direct) shooting support system - computing target acquisition and response management (real-time)
3. Request "routes" to approach building -- with regards with enemy line of sights, etc.
4. Request for a communication "map" (coverage, dead spots) for inside the building
   - indicator for "route" selection and for relay positioning
5. Need reception of display of route information in a dynamic way
   - taking into account any new information that becomes available at higher levels (optipath).
   - Alternative routes
   - Map and event overlays
6. Request routes for access, exit based on the situation awareness (dynamic of the situation)
7. Request an analysis for best actions for crowd control
   - e.g. road blocks established to channel the crowd in A favorable location
8. Information on the people (red and white) in the houses?
   - Prediction of their actions (for example if they are moving in the house, what will be their probable intention?)

SUMMARY

Path planning during operation / movement
- Identify alternate routes and assist rerouting of traffic
- Identify aves of approach/routes (blue, medevac etc.)

Prediction of enemy actions
- Identify aves of approach/routes (red.)

Analysis of capability performance in urban enviroment
- Blast analysis for building
- Weapons coverage
- Range effects
- Communications coverage
- Courses of Action support

Long Planning Time - Command & Control

BAT

1. Medical Treatment and MEDEVAC
   - Communications with local paramedics/doctors
2. Determine location for return of IDPs
3. Use of LOC by civilians also?
4. Locate predetermined fire points
   - Red force HQs targeted
   - NRT comms with fire support assets
   - communicate blue force locations to fire/air support relative to target automatically
5. Logging of all data
   - For legal reasons
   - For playback
   - For AARs

COY/PLT

1. Establish contact with local police and learn if they have tear gas, water cannons and other nonlethal implements
   - Consider using immobilising darts from the zoo
2. Require from higher level assessment of relative importance between objective A and objective B

SUMMARY

Long term communications with factions.
- Establish liaison

Long term communications with Police, NGO, Population representatives

Determine plan for stabilisation of the region including force protection and sustainment
- Location for compound, IDP etc
- Establish medevac plan, Heli landing sites
- Determine objectives of forces and importance of objectives.

Establish command and control structure
- Locate predetermined fire points
- Logging of all data.

Short Planning Time - Command & Control

BAT

1. Communicate w/ adjacent units
   - If adjacent units are another NATO nation, need language conversion for liaisons
   - The bottom line is that units need Blue Force Information on adjacent units!!!
2. Medical Treatment and MEDEVAC
   - Forward soldier conditions to hospital
   - Call for air MEDEVAC for soldiers
3. Rioters move to contact w/ NATO forces (Vignette 2)
   - Notify Police for support
   - Coordinat ASAP w/ Police
   - Request to shutdown their comms
   - Request Media involvement
   - Request CAS support as show of force
4. Request Air Support for units moving west (Vignette 2)
5. Coordinate indirect fire and aviation deconfliction
   - WARNORD to aviation support
6. Alert QRF to situation
   - alert aviation support/heli landing sites
7. Contact Local Authorities and Local Leaders
8. Notify subordinates to change alert state: RAPIDLY
9. Red Forces initiate riot at University (Vignette 2)
   - C Coy notified to support B Coy w/ 1 PLT: needs route
   - C Coy notified to support A Coy w/ 2 PLTs: needs route
   - B Coy desires non-lethal options
10. Inform parties involved
    - Inform ethnic leaders as required
    - Inform municipal govt
    - Inform NGOs
11. Battalion commander on site needs full connectivity to CP
12. Control traffic lights
    - non combatant maneuver
19. Attempt to make contact w/ Zack leader (Vignette 3)
    - Need translator to negotiate w/ Zack leader
    - Record everything Red leader says on phone
20. Media/PSYOPs communications
    - Notify local population that Blue movements are precautionary
21. Need to counter Zack propaganda that they were supporting peaceful demonstration
    - Block Zack media distribution
    - PSYOPS

COY/PLT

1. Request for deployment of battalion/brigade assets
   - Ask to prepare Fire Support on the parks in our AOR
   - Ask for availability (reaction times) of close air support.
   - Request for (all-caliber) gun-firing detection.
   - Request indirect-fire against APCs through laser designation (possible by air and/or land -- UAV or UGV)
   - Request for communication jamming (to use on call - assault for instance)
   - Request to battalion cmdr for support to control the rest of the AO in order to let the coy cmdr focus on the containment of the campus area
   - Request to battalion cmdr to take care of covering the actions of B-coy in the south from the possible enemy firing from the northern house
2. Request for advice
   - Request for legal advices
   - Rules concerning accidents
   - Request for media advices (communication purposes)
3. Requests on Rules of Engagement
   - Can we use direct and indirect fire support (request to battalion cmdr)?
   - The possibility of the use of smoke (in order to cover the action at the house in the south from possible enemy firing from the northern house)
   - Request to battalion cmdr if helicopters might be used to launch Hellfires at the house
   - E.g. mortars to influence them psychologically (mental component)?
   - Require orders regarding our COA with respect to the hospital (fight inside or not)
4. Ask an extension of our AOR at Victoria Park
5. Establish contact with local police and learn if they have tear gas, water cannons and other nonlethal implements
   - Establish contact with local police and learn if they have tear gas
   - Consider using immobilising darts from the zoo
6. Report to higher level info about traffic jam -- (direct consequence on availability of routes) (Vignette 1, event 1)
   - Define new routes west of the primary one, to be taken by the convoy
   - Request to use route(s) that belong to the responsibility of the neighbouring units
   - Request possibility to MEDEVAC by AIR (helicopter) due to trafic jam
7. Request to commander for information on coordination with neighbouring units, along with Course of Action
8. Request of action for police involvement (through liaison or higher level)
9. Request consequences for the mission -- delay, threats, alternate routes, etc.

10. Request for police assistance and local ambulance(s) for civilian casualties
11. Overhead Imagery
    Imagery must be passed thru Coy to Platoon

SUMMARY

Coordination of PsyOps campaign in the light of current events
- Using media
- Block media distribution by factions

Coordination with adjacent units, police and NGO's
- For medical purposes
- For support eg CRC
- Deconfliction with other units

Communication with factions/etnic groups
- Inform and negotiation

Requests for ROE

Requests for deployment of higher level assets
- Fire support, Aviation, CAS

Reports on current situation
- Upwards eg Sitreps
- Downwards eg imagery

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14. Abstract

SET-076 was commissioned to define the sensing problem posed by operations in urban environments, to identify shortcomings in current capabilities, and to identify promising research to help fill those gaps. This report documents the findings of the group.

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