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A literature review in urban operations and recommendations for future research

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Abstract

This document presents a literature review covering the most recent (i.e., last five years) research activities that occurred in the field of urban operations within international research organizations such as NATO Research and Technology Organization (RTO), The Technical Cooperation Program (TTCP) and the organization supporting the armies of United States, United Kingdom, Canada and Australia and known as ABCA (America, Britain, Canada and Australia). It aims to identify potential areas of interest that have not been addressed yet by these organizations and which might benefit from a concerted international effort. Six such areas have been identified: Logistics Support, Human Factors, Movement and Manoeuvre, Asymmetric Force Protection, Special Operations, and Interaction with Non-Governmental Organizations.

Résumé

Ce document présente une revue de la littérature des activités de recherche récentes (des cinq dernières années) dans le domaine des opérations urbaines qui ont eu lieu au sein des organisations de recherche internationales, telles que l'organisation pour la recherche et la technologie (RTO) de l'OTAN, le programme de coopération technique (TTCP) et l'organisation connue sous le nom ABCA offrant du support aux armées des États-Unis, de la Grande-Bretagne, du Canada et de l'Australie. Cette revue a pour objectif d'identifier des avenues de recherche qui n'ont pas encore été abordées par ces organisations et qui méritent d'être explorées. Six avenues de recherche futures ont été identifiées : le soutien logistique, les facteurs humains, les mouvements et manœuvres, la protection des forces armées face aux menaces asymétriques, les opérations spéciales et l'interaction avec les organisations non gouvernementales.

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Executive summary

Urban operations are likely to become among the most common operations in the future. These operations are expected to be both unavoidable and difficult to conduct. Some of the inherent difficulties associated with conducting combat or non-combat military operations in urban areas are related to the complexity of the physical environment (presence of man-made structures such as buildings and developed underground areas), to the requirement to preserve the infrastructure (transportation network, utilities, medical services, etc.), and to the presence of large number of non-combatants whose security must be ensured.

There are presently many national and international efforts aiming to address the challenges related to urban operations. The purpose of this document is twofold. First, it aims to present a literature review of the research activities conducted during the last five years in the field of urban operations within international research organizations such as NATO-RTO, TTCP and ABCA. Second, it aims to identify potential areas of interest that had not been addressed in the past by these organizations and that may benefit from a concerted international effort in the future.

To reach these objectives, the first step consisted of gathering the relevant information from all available sources. Then, a systematic approach was used to sort and organize this information. The adopted approach consisted of mapping the reviewed research activities to a methodical description of the general subject of urban operations. Such a description was obtained through the USECT framework: *Understand, Shape, Engage, Consolidate, and Transition*, correlated to a list of the main operational tasks that are generally encountered in each phase of this framework.

Based on this approach, the literature review revealed two categories of research activities. Activities in the first category address the subject of urban operations at a higher level, attempting to provide a general view covering most or all stages within the USECT framework. Activities in the second category have a narrower focus, addressing only some of the operational tasks associated to some of the stages in the USECT model, but they do so at a lower level, attempting to provide a closer view of the subject considered.

The mapping process described above can also be viewed as fitting the pieces of a puzzle. In this context, the USECT framework is used to define the boundaries of the “puzzle” representing the field of urban operations. The research activities reviewed in this paper represent the available pieces

of the puzzle, while the missing pieces, which can be spotted at a glance under the proposed approach, represent areas that have not been addressed yet within the research organizations mentioned before. I.e., they represent good candidates for future research, new avenues to explore that will allow for a better understanding of the complex field of urban operations.

Among the multitude of issues that could still benefit from a concerted international research effort, three were selected by the authors as prime candidates for initiating such an effort (1 to 3 below). The reasons behind this selection were two: the *high importance* of the issue towards achieving success when conducting an urban operation, and the fact that the subject was *not tackled before* within the research organizations considered in this study. Upon lecture of a preliminary version of this document, members of the TTCP Joint Systems and Analysis (JSA) Group notified the authors about three additional areas that were of particular interest to them (4 to 6 below). As such, six topics were retained as good potential candidates for future research, as follows:

1. **Logistics Support:** The context of urban operations creates many challenges in terms of logistics support, mainly because of the complexity of the physical terrain and the presence of a large number of non-combatants. For example, the distribution process is more complicated as the supplies (ammunition, food, water, etc.) need to be delivered on several floors of a building, and sometimes manhandled up the stairwells. Also, the presence of non-combatants will create an additional burden for medical or supply services. Thus, it is recommended to address the problem in its entirety, from a clear definition of the logistics requirements in urban operations, up to the proposal of solutions to respond to those requirements.
2. **Human Factors Issues:** The human dimension is one of the most important issues in urban operations. However, relatively little effort was spent on addressing human issues when compared to the effort spent on addressing materiel issues. Examples of areas that could be addressed in the vast domain of human factors include the following: identifying the type of skills and training that are needed to ensure that soldiers will be fully prepared to operate in urban terrain, analyzing interoperability issues from a personnel point of view, analyzing organizational issues and current or proposed rules of engagement, or analyzing the human performance issues in urban military operations.
3. **Movement and Manoeuvre:** The freedom of movement and the ability to manoeuvre can be significantly hampered by the presence of non-combatants, refugee movement, or by the transportation

infrastructure. The presence of buildings and the difficulty to clear buildings of potential threats (snipers, for example) will make movement slow. Other characteristics of an urban terrain, such as short lines of sight and a multitude of potential hiding places for the enemy increase the complexity. Thus, traditional theories of movement and manoeuvre, developed for open battlespaces, become obsolete in an urban context characterized by a multitude of smaller battlespaces that need to be tackled separately but in a coordinated manner. The subject of making the transition from the classical theory of movement and manoeuvre in open spaces (based on linear concepts) to a theory that is applicable to urban terrain (where non-linear infiltration tactics are required), as well as the related implementation issues are two important pieces of the puzzle that could greatly benefit from attention from the scientific community.

4. **Asymmetric Force Protection:** Asymmetric tactics, ambushes, suicide bombings and hostage taking are becoming more and more common in today's international operations and the question of how to protect deployed personnel from these threats is accordingly gaining more and more importance. Hence, it is expected that research conducted in this domain would be most welcome by the operational military community, which makes it another important piece of the puzzle. Some of the topics that could be addressed in this field include the development of intelligence capabilities against asymmetric threats, issues related to the equipment required to improve perimeter security, or issues related to the training of personnel to better respond to the terrorist threats. Another question that could be addressed is to identify how to better achieve force protection by developing psychological operations, public affairs and civil-military operations.
5. **Special Operations:** The complexity of the urban environment and the need to counter terrorist attacks in such an environment give a crucial role to special operations. Among the issues that could be tackled in this field are included the following: the study of the communication links between C4ISR capabilities and Special Operations Forces (SOF), the identification of the type of skills and training required for members of SOF, the assessment of operational benefits and risks related to the deployment of SOF among the local population and the legal constraints that might affect such operations, especially in a multi-national urban context.
6. **Interaction with Non-Governmental Organizations (NGO):** In an urban environment, due to the presence of non-combatants, NGOs are bound to exist and probably in large numbers. For example, during the

peace support operations conducted in Bosnia, over 400 such organizations were active. In the interaction between the NGOs and the armed forces, concepts such as “coordination of efforts”, “mutual support” and “collaboration” are very important, but also very difficult to implement. As such, the research avenues that address some of the challenges encountered in the implementation of these concepts look promising. Among the directions such research could take, the following could be mentioned: dealing with the communication issues that are bound to appear when such a large number of players is involved, managing the consequences of the fact that sometimes the military and the NGOs have different objectives, different timeframes and also different views on the best ways to reach these objectives, dealing with the heterogeneous structure of the NGOs, or with the mutual lack of understanding of the roles and capabilities of the NGO and the military communities.

Based on the literature review conducted for this study and on the authors’ interpretation of this literature review, six areas have been identified as good potential candidates for further research in the field of urban operations. Within the six areas, several problems that could be tackled were also identified. However, the results presented in this paper are by no means a comprehensive list of issues, they are mainly provided as a starting point to foster further discussions among the scientific community regarding the present and the future in urban operations.

AF, LS. 2006. A literature review in urban operations and recommendations for future research. DRDC-Valcartier TM 2006-171. DRDC Valcartier.

Sommaire

Les opérations militaires en milieu urbain vont probablement devenir de plus en plus la règle et non pas l'exception. On s'attend à ce que ces opérations soient à la fois inévitables et difficiles à mener. Parmi les difficultés qui leur sont associées, que ce soit en situation de combat ou non, figurent la complexité de l'environnement physique (présence de structures construites par l'humain comme des bâtiments ou des sous-terrains), la nécessité de préserver l'infrastructure (réseau de transport, alimentation en eau et électricité, services médicaux, etc.) et la présence d'un grand nombre de non-combattants pour lesquels il faut assurer la sécurité.

Plusieurs efforts de recherche nationaux et internationaux sont entrepris pour relever les défis associés aux opérations urbaines. Ce document a deux objectifs principaux. Le premier est de présenter une revue de la littérature des activités de recherche récentes (des cinq dernières années) dans le domaine des opérations urbaines, qui ont eu lieu au sein des organisations de recherche internationales, telles que RTO, TTCP et ABCA. Puis, le second objectif est d'identifier des avenues de recherche qui n'ont pas encore été abordées par ces organisations et qui méritent d'être explorées dans des activités internationales futures.

Pour atteindre ces objectifs, la première étape a été une cueillette d'information de toutes les sources disponibles. Ensuite, une approche systématique a été utilisée pour trier et organiser ces informations. L'approche adoptée consiste à classer les activités internationales qui ont été revues selon une description méthodique du sujet des opérations urbaines. Une telle description a été obtenue par l'utilisation de la structure USECT (*Understand, Shape, Engage, Consolidate, and Transition*) préalablement corrélée à une liste de tâches opérationnelles généralement rencontrées dans chacune des phases de USECT.

Basée sur cette approche, la revue de la littérature a révélé deux catégories d'activités de recherche. Les activités de la première catégorie traitent le sujet des opérations urbaines à un haut niveau, fournissant une vue générale sur la plupart, sinon la totalité des phases de la structure USECT. Les activités de la deuxième catégorie sont de plus petite envergure, abordant seulement certains aspects particuliers liés à un type d'opération donné et, généralement, à une seule phase de la structure USECT. Ces activités tentent d'aborder le problème à un plus bas niveau, offrant une vue plus approfondie du sujet en question.

L'approche décrite ci-dessus peut aussi être vue comme le processus de reconstitution d'un casse-tête. Dans ce contexte, la structure USECT sert à définir les frontières du casse-tête représentant le domaine des opérations urbaines. Les activités de recherche rapportées dans cette revue de la littérature peuvent être vues comme les morceaux disponibles du casse-tête, alors que les parties manquantes, facilement identifiables par l'approche proposée, constituent les avenues de recherche qui n'ont pas encore été étudiées par les organisations en question. Celles-ci représentent de bons candidats pour les recherches futures et de nouvelles avenues à explorer qui vont permettre une meilleure compréhension du domaine complexe des opérations urbaines.

Parmi les avenues de recherche qui peuvent être explorées par les organisations de recherches internationales, trois ont été sélectionnées par les auteurs (1 à 3 ci-dessous) en se basant sur l'importance du sujet à étudier et sa contribution potentielle au succès des opérations urbaines ainsi que sur l'absence de recherches sur le sujet en ce qui a trait aux organisations de recherche internationales. Par ailleurs, suite à la lecture d'une version préliminaire de ce document par les membres TTCP du groupe JSA (Joint Systems and Analysis), trois autres sujets d'intérêt pour le groupe ont été identifiés (4 à 6 ci-dessous). Par conséquent, six sujets ont été retenus comme de bons candidats potentiels pour les recherches futures :

- 1- **Soutien logistique** : Le contexte des opérations urbaines crée plusieurs défis en matière de soutien logistique, et ce principalement à cause de la complexité du terrain et de la présence d'un grand nombre de non-combattants. Par exemple, le processus de distribution est plus complexe lorsqu'il s'agit de livrer les approvisionnements (munitions, nourriture, eau, etc.) dans des bâtiments à étages. De même, la présence des non-combattants crée des demandes additionnelles de services médicaux et de services d'approvisionnement. Donc, il est recommandé d'aborder le problème du soutien logistique dans son ensemble allant d'une définition des besoins logistiques des opérations urbaines, à la proposition de solutions pour répondre à ces besoins.
- 2- **Facteurs humains** : La dimension « facteurs humains » est très importante dans les opérations urbaines. Ceci dit, peu d'efforts ont généralement été consacrés pour traiter ces aspects comparés aux efforts voués aux aspects matériels. Parmi les avenues de recherche qui pourraient être explorées dans ce vaste domaine des facteurs humains figurent : l'identification des qualifications et des formations requises pour s'assurer d'une préparation adéquate des soldats aux opérations urbaines ; l'analyse des problèmes d'interopérabilité du point de vue du

personnel ; l'analyse des problèmes organisationnels et des règles d'engagement et l'analyse de la performance de l'humain dans les opérations militaires dans un environnement urbain.

- 3- **Mouvements et manœuvres** : Les mouvements et les manœuvres des forces sont entravés par la présence des non-combattants, par le mouvement des réfugiés et par l'infrastructure de transport. La présence de bâtiments qui peuvent dissimuler des ennemis va ralentir les mouvements. D'autres caractéristiques du terrain urbain comme les courtes lignes de vue et la multitude d'endroits où l'ennemi pourrait se cacher ajoutent à la complexité. De là, les théories traditionnelles des mouvements et des manœuvres, développées pour les espaces ouverts, deviennent obsolètes dans un contexte urbain qui se caractérise par une multitude de champs de bataille. La communauté scientifique au sein des organisations internationales pourrait se pencher sur l'adaptation de la théorie classique des mouvements et manœuvres sur des terrains traditionnels (basée sur des concepts linéaires) à une théorie qui serait applicable dans un contexte urbain (où des tactiques d'infiltration non linéaires seraient requises) ainsi que sur l'étude des problèmes d'implantation qui lui seraient liés.
- 4- **Protection des forces armées contre les menaces asymétriques** : Les tactiques asymétriques, les embuscades, les attaques-suicide et la prise d'otages deviennent des événements de plus en plus communs dans les opérations militaires internationales courantes, ce qui fait que la question de la protection du personnel déployé contre ces menaces prend de plus en plus d'ampleur. Par conséquent, on s'attend à ce que les recherches entreprises dans ce domaine soient très bien reçues par la communauté militaire, ce qui rend cette direction de recherche une des pièces importantes du casse-tête. Parmi les sujets qui pourraient être abordés dans ce domaine, on peut inclure les points suivants : développer de meilleurs services de renseignements contre les menaces asymétriques, régler les questions entourant l'équipement nécessaire pour améliorer la sécurité sur un périmètre, ou encore régler les questions entourant l'entraînement du personnel militaire pour mieux répondre aux menaces terroristes. Un autre sujet qui pourrait être abordé est l'identification des façons d'obtenir une meilleure protection des forces armées par les opérations psychologiques, les affaires publiques et les opérations civiles-militaires.
- 5- **Opérations spéciales** : Le niveau de complexité élevé de l'environnement urbain ainsi que le besoin de répondre aux attaques terroristes dans un tel environnement donnent un rôle crucial aux opérations spéciales. Parmi les sujets qui pourraient être abordés dans

ce domaine, on peut inclure : l'étude des liens de communication entre les services de renseignements et les forces spéciales, l'identification des capacités et des types d'entraînement qui sont nécessaires aux membres des forces spéciales, l'évaluation des risques et des bénéfices opérationnels liés au déploiement de forces spéciales parmi la population locale, ainsi que l'étude des contraintes juridiques qui pourraient affecter ces opérations, particulièrement dans un milieu urbain et dans un contexte multinational.

- 6- **Interactions avec les organisations non gouvernementales :** Dans un environnement urbain, il est très probable qu'un grand nombre d'organisations non gouvernementales (ONG) soient présentes, surtout à cause du nombre élevé de non-combattants. Par exemple, durant les opérations de maintien de la paix en Bosnie, plus de 400 organisations étaient actives. En parlant de l'interaction entre les forces armées et les organisations non gouvernementales, des concepts comme « coordination des efforts », « soutien mutuel » et « collaboration » deviennent très importants, mais ils sont aussi très difficiles à implanter. Par conséquent, les directions de recherche qui visent à relever certains défis apparaissant dans l'implantation de ces concepts sont prometteuses. Parmi elles on peut mentionner les points suivants : aborder la problématique de la communication impliquant un grand nombre de participants; gérer le fait que les forces armées et les organisations non gouvernementales ont des objectifs différents, des horizons de temps différents ou encore des vues différentes quant aux façons d'atteindre ces objectifs; gérer les difficultés occasionnées par la structure hétérogène des ONG, ou encore par l'incompréhension réciproque des rôles et capacités respectives des ONG et des forces armées.

Suite à la revue de la littérature effectuée pour cette étude et à l'interprétation que les auteurs ont donné à cette revue de la littérature, six domaines ont été identifiés comme de bons candidats pour des activités de recherche futures sur le sujet des opérations urbaines. Dans ces six domaines, plusieurs avenues de recherche ont été également identifiées. Les résultats présentés dans ce document ne représentent pas une liste exhaustive d'avenues de recherche, ils sont plutôt proposés comme un point de départ pour d'autres discussions à l'intérieur de la communauté scientifique portant sur le présent et le futur des opérations urbaines.

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1. Introduction

Background

The expected demographic trends show that both population growth and migration to cities are factors that lead to an urban world and to a change in the fundamental characteristics of many conflicts, whether tribal, ethnic, religious, or ideological. In fact, demographic studies show that the world's urban population is growing four times as fast as its rural population, and 150,000 people are added to the urban population of developing countries every day [1, 2]. It is anticipated that by 2025, two-thirds of the earth's population will live in urban areas, and 90 percent of the growth will be in the developing world [1]. As population shift from rural to urban areas, it is expected that conflicts and war will also shift to urban areas [2, 3, 4, 5]. As a result, urban operations are likely to become among the most common operations in the future.

In this document, *Urban Operations* will describe any military activity that occurs in urban areas ranging from humanitarian assistance to conventional combat. In the military literature, there are also other terms that are used to describe operations in urban areas including: Urban Combat, Fighting In Built-Up Areas, Military Operations in Built Up Areas, Military Operations on Urbanized Terrain, Operations in Complex Terrain, Urban Military Operations, etc.

In the past, urban operations were mostly encountered in the context of peacekeeping or relief from natural disasters. It is expected however that future urban operations will cover the entire range of military operations, from war to Military Operations Other than War (MOOTW) [5].

An important characteristic of urban areas is the presence of **large, concentrated populations** of civilians whose security must be preserved. In addition to this major goal of preventing life losses among the civilian population, two additional objectives should be considered: to minimize the interference with military operations, and to observe the necessary legal, moral, and humanitarian obligations [5].

Additional constraints are imposed by the **complexity of the physical environment**, with both natural and man-made elements. In urban areas, the geometry is 3D (length, width, height). In addition to airspace and surface areas, there are manmade super-surface (upper floors of buildings) and sub-surface areas (below ground areas such as subways). The potential problems are distributed over a volume. By unit of volume, there are

necessarily more innocent civilians, more enemies and more friendly force personnel who can be accidentally killed or injured [5]. Furthermore, the many windows, doors and openings allow for more possible firing positions. Thus, many challenges exist and should be dealt with.

Another aspect is the **infrastructure**, which may be relatively simple or may be highly complex and sophisticated. On one hand, urban areas will contain a physical infrastructure, which at a minimum includes a transportation network, utilities, government buildings, hospitals, schools, distribution centers, and communications facilities. On the other hand, cities also have a service infrastructure that includes police, fire, and other government services; food and water availability and distribution; medical services; fuel and electricity; the news media and information flow; and others. Loss of any of these elements of infrastructure may have catastrophic consequences and sometimes a heavy cultural or social cost (ex: heritage assets) [5].

Other issues that complicate urban operations are related to **asymmetric threats** and the changing nature of the enemy. For example, it is easier for guerrillas, insurgents and other non-state groups to operate in an urban environment. They can move more freely and effectively in crowded urban areas since the detection and identification of hostile elements among a densely non-combatant population are extremely difficult.

Each one of the characteristics discussed above increases the complexity of military operations in urban areas, but, as concluded by [5], the *interaction* between them adds an additional level of complexity making each urban area a **complex and dynamic system of systems**, with a unique physical, political, economic, social and cultural identity.

The nature of urban conflict is changing. In the more remote past, the fighting took place in urban areas between conventional ground forces seeking to gain a city in the context of a major war such as World War II. In the recent past however, the nature of conflict has radically changed with asymmetric threats. Insurgencies, transnational terrorism in the world's cities and civil wars are likely to become the most common form of urban conflicts in the future [2]. This new form of conflict should receive attention in the military communities because of its complexity and its expected increase in frequency. Effective means and capabilities to conduct those urban operations with success should be prepared carefully. Present capabilities for operating in urban areas are essentially those of World War II, which are characterised by high levels of casualties and extensive collateral damage [4]. Thus, it is essential to provide additional options and capabilities that would allow avoiding such consequences.

Purpose

There are presently many national and international efforts aiming to address the challenges related to urban operations. This document aims to present a literature review covering the most recent (last 5 years) activities in the field of urban operations that occurred within the following international research organizations: NATO-Research and Technology Organization (RTO), TTCP and ABCA, with a view to identify potential areas of interest that have not been addressed yet by those organizations and which might benefit from a concerted international effort.

Organization of the Document

This document is structured as follows. After this Introduction, Section 2 presents the approach that was used to conduct this work and produce the results. Section 3 describes the recent international activities that deal with urban operations. It is focused on the activities (either completed or ongoing) conducted within NATO RTO, TTCP and ABCA organizations. For each activity, the aim and specific objectives are introduced first, followed by the approach used to reach these objectives and finally by the main results (for completed activities) or preliminary results (for ongoing activities). Then, Section 4 combines the results of Sections 2 and 3 to identify potential areas of interest that have not been addressed yet by these organizations and which might benefit from a concerted international effort. Finally, Section 5 is dedicated to some concluding remarks.

2. Approach

The main mandate for this work was to carry out a literature review of the activities conducted in the recent past in international research organizations NATO-RTO, TTCP and ABCA in the field of urban operations, aiming to identify potential areas of interest that had not been addressed in the past by these organizations and that may benefit from a concerted international effort in the future.

To reach this objective, the first step was gathering the information about the past research activities that were conducted within the organizations mentioned above, in the field of urban operations. Other publications in this field, issued from different sources, had also been reviewed, so that a more complete picture can be obtained and thus allow for a better understanding of how the RTO, TTCP and ABCA research activities are positioned in the bigger picture. Significant efforts were made by the authors during the time available for this study to collect this information; however, no claim can be made about the comprehensiveness of this literature review.

This being said, the quantity of information gathered was important. A systematic approach was needed to sort and organize this information to ensure that the purpose of conducting this literature review could be attained. The adopted approach consisted of mapping the research activities being reviewed to a methodical description of the general subject of urban operations, which allowed for the identification of areas of interest in urban operations that had not been covered yet by any research activity (of the ones reviewed in this document). These areas could then constitute good candidates for future research.

More precisely, the description of the general subject of urban operations was obtained through the framework provided by a widely accepted model of the battlespace: *Understand, Shape, Engage, Consolidate, and Transition* (USECT). This model was first introduced by the US Department of Defence in a joint doctrinal publication on operations in an urban environment [5] and later obtained the endorsement of NATO's RTO. This model will be described in more detail in a further paragraph. For now, it will only be mentioned that this framework does not only apply to the urban operations, but also to operations in other types of environments and that it represents a more universal battlespace model than the traditional *Find, Fix and Strike*.

Within the USECT framework, the next level of detail in the description of the subject of urban operations is provided through a listing of the main operational tasks in each of the five phases of USECT that are generally encountered in military operations, along with their particularities in the case of urban operations. More detail about the operational tasks will be provided later in this section.

The mapping of the research activities reviewed in this paper is done at the operational tasks level, attempting to identify which of these have been covered (at least to some extent) by the research activities and, by the same token, identify which of the operational tasks have not been tackled yet and could make good candidates for future research.

2.1 The USECT Framework

When dealing with urban operations, a framework frequently used by international publications as a basis for planning and conducting operations in urban areas is the USECT framework [4, 5]. USECT consists of five phases: *Understand*, *Shape*, *Engage*, *Consolidate*, and *Transition* (Figure 1). These phases evolve in an interdependent, continuous, and simultaneous way. They may be sequential or concurrent and may often overlap. In some cases, all five phases may not be required and in other cases, some phases may have to be conducted more than once [4].

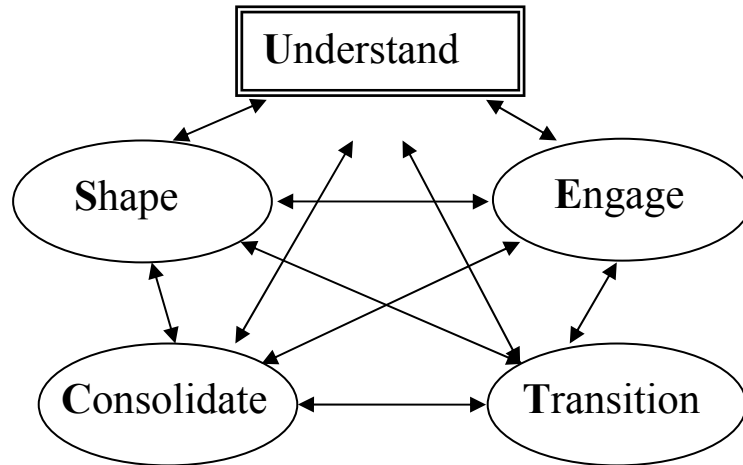


Figure 1: The USECT Framework

This framework aims to understand the nature of the enemy, its locations and intentions before engagement and to use the information gained to shape the urban battlespace. Understanding is continuous while shaping, engagement, consolidation, and transition may be considered as sequential but strongly interrelated. Next, definitions of each phase, as provided in [4, 5], are also included here, for the reader's convenience.

Understand. This phase includes the evaluation of physical terrain, buildings, cultural centres and critical infrastructure such as utilities, transportation systems and hospitals. It also consists in assessing all relevant forces, groupings, cultural and religious factors and identifying critical nodal points in the urban area. The understanding of the ethnic and religious composition of the population and their intent is also crucial.

Shape. This phase includes all actions taken to set favourable conditions for the subsequent phases of engagement, consolidation and transition. It includes the strategic movement of forces into theatre, operational fires outside the urban area, force protection and air and maritime superiority. It also consists in isolating the battlespace. This isolation is not only physical but also informational and moral. The “Shaping” phase also includes the establishment of refugee camps for non-combatants, arrangement of safe passage for them and emergency services.

Engage. This phase can range from large-scale combat operations to humanitarian assistance and disaster relief. The engagement phase directly address decisive points on the line of operations aimed at the adversary’s centre of gravity. It includes actions against a hostile force, a political situation, or natural or humanitarian assistance.

Consolidate. This phase consists in protecting what has been gained and gaining an advantage in tempo (spatial, psychological, and informational) over the adversary. Consolidation may also require the use of liaison and cooperation with local authorities and other agencies.

Transition. This phase consists in transferring the control of the urban areas to the local civilian authorities or sometimes to an international organisation. More specifically, it includes the resettlement of displaced civilians and the reconstitution of national military forces if appropriate.

2.2 Operational Tasks

Ref [5] gives an overview of the main operational tasks encountered in military operations and discusses how they may be different in an urban context. As a good understanding of the operational tasks and their specificities in the case of urban operations is essential for the general comprehension of this document, a resume of the main conclusions of [5] is included here, for the reader’s convenience.

Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR)

C4ISR are fundamental to the conduct of operations in general. The related capabilities process and integrate information and distribute it to where it is needed. Capabilities of C4ISR include the use of air and space sensors coupled with Human Intelligence (HUMINT) sources.

C4ISR are crucial for the *understand* and *shape* phases but can sometimes be useful for the *engage*, *consolidate* and *transition* phases. On one hand, intelligence, surveillance, target acquisition and reconnaissance are central to the Understanding phase. On the other hand, the ability to implement command decisions based on changing information is critical to shaping the battlespace. Moreover, in urban operations, HUMINT is essential in understanding the local behaviour and psychology, identifying targets, and developing situational awareness.

The C4ISR capabilities should be adapted to the urban context and should take into account urban structures, clutter, background noise, and the difficulties to see into interior spaces. In fact, the complex manmade physical terrain along with the presence of non-combatants, reduce the performance of C4ISR capabilities and degrade navigation and position/location information.

Movement and Manoeuvre

Movement aims to place ships, aircraft, or land forces in a position of advantage over the enemy. Manoeuvre consists of the tactical or operational actions that should be taken to engage or disrupt adversaries or to destroy their ability to achieve planned objectives (ex: turning movement, infiltration, penetration, frontal attack, etc.). Tactical and operational movement and manoeuvre are important for the *shape* and *engage* phases. Whereas movement puts forces in the best advantage position, manoeuvre can reduce the amount of combat necessary to defeat the enemy.

Because of the constraints imposed by urban areas, movement and manoeuvre above, below, and on the ground, as well as within or among structures, should be multidimensional, aimed not only at geographic decisive points, but also on key events. Actually, the nature of the physical terrain (structures, buildings) and the presence of non-combatants can act as an impediment to both movement and manoeuvre and make them difficult.

Fires

Fire consists of the use of lethal and non-lethal weapons to reach operational objectives. It can be used to *shape* the battlespace and to *engage* the adversary. In urban operations, the most important use of fires remains in the isolation of the urban area.

The use of fire in urban operations is challenging because of the nature of the physical terrain (height and proximity of buildings, different types of structures, construction material, and structural density), the presence of non-combatants and the necessity to preserve the infrastructure. Taking in consideration all these elements, activities of firing require careful planning and coordination to avoid non-combatant casualties and collateral damage. Undesired consequences of fires can include displacement of the civilian population or the destruction of critical infrastructure. The effective use of fire in urban areas necessitates the integration and synchronization of forces and a clear knowledge of rules of engagement. Also, the use of non-lethal weapons may constitute a good alternative to shape the battlespace while minimizing non-combatant casualties and collateral damage.

Logistics support

Activities of logistics support deal with the design, development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposal of materiel but they also cover the movement, evacuation, and hospitalization of personnel and the acquisition of facilities and services. Examples of logistics support needed in general are: equipment maintenance, reconstitution of units, water and food supply and delivery, personnel clothing and equipment replacement, health services, transportation management, etc. Logistics support with all its facets is important for the *shape*, *engage*, *consolidate* and *transition* phases.

Logistics support is more difficult in urban operations due to the high level of injury and exhaustion of personnel, damage to equipment and support to non-combatants. In fact, the need to operate in buildings and streets can have an effect on mobility and brings a variety of medical challenges. In addition, the large number of non-combatants increases sickness and injury potential and inhibits vehicle movement.

Force Protection

Force protection (FP) regroups all actions taken to prevent hostile actions against personnel, resources, facilities, and critical information. The general aspects of FP include: protection and security of operational forces

and non-combatants, protection of systems and capabilities and the conduct of deception operations. FP actions should be conducted during the *shape, engage, consolidate* and *transition* phases.

Urban areas pose significant FP problems because of the nature of urban terrain and essentially because of the presence of non-combatants. In fact, their large number and their distribution inhibit protective fires and complicate the evasion and personnel recovery. Also, the protection of the infrastructure, mostly the security of civilian buildings and communications is a challenge for the friendly units.

Consequence Management

Consequence management (CM) consists of measures taken to protect public health and safety, restore essential government services, and provide emergency relief to governments, businesses, and individuals. Actions that can be taken are: population evacuation, decontamination, transportation, communications, public works and engineering, firefighting, information and planning, mass care, resource support, health and medical services, urban search and rescue, hazardous materials control, food distribution, and energy provision. CM is important for the *consolidate* and *transition* phases of the USECT framework. Due to the increased emphasis on urban operations in the future, CM will gain more importance in urban areas. The nature of physical terrain and infrastructure on one hand and the civilian population on the other hand increase the necessity of CM.

Space Operations

The information provided by space-based systems can improve situational awareness and help enable information superiority. Space-based systems include: precision global navigation, communications, ISTAR, command and control (C2) warfare including counter ISTAR activities, the use of electronic warfare, etc. Space operations are important for *all the phases* of the USECT framework ranging from the *understand* phase to the *transition* phase. In urban areas, space operations, as a platform for information operations, suffer in some cases from the urban clutter and the difficulties in penetrating interior spaces.

Special Operations

Special operations are operations conducted by military or paramilitary forces to achieve military, political, economic, or informational objectives by unconventional military means. There are many objectives of special operations: fighting terrorism, counter-proliferation of weapons of mass

destruction (WMD), information operations, civil affairs, psychological operations, etc. Special operations intervene in *all the phases* of USECT framework from the *understand* phase to the *transition* phase.

Information Operations

Information operations consist of the use of offensive and defensive information means to degrade, destroy, and exploit an adversary's information-based process while protecting one's own. They aim to control the information environment and influence the thoughts and opinions of adversaries and noncombatants over radio, television and other media sources. Information operations actions are crucial. They should be conducted to *shape* the battlespace and also to *engage* the adversary.

Psychological Operations

Psychological operations (PSYOPs) consist in conveying selected information and indicators to influence the emotions, motives, and behaviours of the civilian population. The purpose of PSYOPs is to induce or reinforce foreign attitudes and behaviours so that they become favourable to friendly objectives. Psychological operations can affect the fighters, their military leaders, the staffs, the political leaders and the civilian population. PSYOP efforts often present challenges for friendly forces and should consider ethnicity, cultural identity, religion or economic factors. In general, PSYOPs intervene to *shape* the urban battlespace, and have an impact *before, during, and after actual engagement*, whether in war or MOOTW.

In urban areas, PSYOP become even more important because of the nature of physical terrain and the infrastructure. In fact, the physical terrain allows the concentration of people and the infrastructure provides means to disseminate information throughout the operational area (television, radio, computers, newspapers, etc.).

Civil-Military Operations

Civil-Military Operations (CMO) regroup those activities of establishing and exploiting relationships between military forces and the civilian population in order to facilitate military operations and to achieve operational objectives. These activities may occur prior to, during, or subsequent to other military actions. CMO may be conducted to *shape* the battlespace or to *engage* a civil problem, but their more likely role is in the *consolidate* phase and the *transition* to civil authority.

In urban operations, the nature of terrain can hamper, fragment and channel the CMO efforts. It may be difficult to find and establish relationships between the civilian in need of support and the military forces. In all cases, effective CMO will require the understanding of neighbourhoods, tribal relations, and the basic allegiances and daily life of the inhabitants.

Personnel Recovery

Personnel Recovery (PR) consists of exploiting the military, civil, and political efforts to obtain the release or recovery of personnel from hostile environments where they are captured, missing, or isolated. PR includes search and rescue, survival, evasion, resistance, and escape as well as the coordination of negotiated recovery options. PR operations should be conducted whenever necessary and this might be during the *engage*, *consolidate* and *transition* phases of the USECT framework.

Table 1 summarizes the correlations between the USECT phases and the operational tasks. For each phase of the USECT framework, the main operational tasks that are generally encountered within that particular phase are provided.

Table 1: Correlation between the USECT Framework and the Operational Tasks

OPERATIONAL TASKS/ USECT PHASES	UNDERSTAND	SHAPE	ENGAGE	CONSOLIDATE	TRANSITION
C4ISR					
Movement and Manoeuvre					
Fires					
Logistics Support					
Force Protection					
Consequence Management					
Space Operations					
Special Operations					
Information Operations					
Psychological Operations					
Civil-Military Operations					
Personnel Recovery					

3. Recent International Research Activities

This section summarizes some of the recent (last five years) international research activities that were conducted in the field of urban operations. They can be identified at a glance in Table 2.

Table 2: Recent International Research Activities in Urban Operations

NATO Research and Technology Organisation			
Activity Number	Title	Dates	Technical Panel or Group
SAS-030	Urban Operations in the Year 2020	06/2000 to 12/2001	Studies Analysis & Simulation (SAS)
SAS-035	Non-Lethal Weapons Effectiveness Assessment	03/2001 to 12/2004	Studies Analysis & Simulation (SAS)
SAS-040	Non-Lethal Weapons and Future Peace Enforcement Operations	05/2001 to 12/2004	Studies Analysis & Simulation (SAS)
HFM-073	Human Effects of Non-Lethal Technologies	04/2001 to 05/2005	Human Factors and Medicine
IST-046	Command Center Challenges for Urban Operations	01/2004 to 12/2006	Information Systems Technology (IST)
SET-090	Sensors for Urban Operations (Workshop)	01/2005 to 01/2006	Sensors & Electronics Technology (SET)
SET-076	Sensor Requirements for Urban Operations	06/2003 to 12/2006	Sensors & Electronics Technology (SET)
TTCP			
SEN-AG9	Urban Sensors Exploratory Study (URSES)	06/2003 to 06/2006	Sensors Group (SEN)
WPN-AG17	Non-Lethal Weapons	02/1998 to 01/2002	Conventional Weapons Technology Group (WPN)
HUM-AG22	Research Design for the assessment of Non Lethal Weapon Human Effects	09/2003 to Fall 2006	Human Resources and Performance Group (HUM)
ABCA			
QAP 273	Concepts for Urban Operations	November 2000	Capability group : Act
QAP 319	Agreeing Capabilities Required to Implement the Common Concept for Urban Operations	June 2004	Capability group : Act
QAP 274	Delivery of Urban Operations Capabilities	June 2004	Capability group : Act
QAP 320	Interoperability Issues in Urban Operations	June 2004	Capability group : Act
QAP 304	Fire Support in Urban Operations	March 2004	Capability group : Act

Others (activities cosponsored by US Marine Corps and US Joint Forces Command)			
JUW04	Joint Urban Warrior 2004	21-26 March 2004	
JUW05	Joint Urban Warrior 2005	21-26 May 2005	

3.1 Urban Operations in the Year 2020 (SAS-030)

SAS-030 is an activity of NATO-RTO that was conducted from June 2000 to December 2001 to investigate the joint and combined doctrine and concepts for operations in urban areas. This activity was developed after the RTO Technical Report *Land Operations in the Year 2020* [3] identified operations in urban areas as a major potential challenge for Alliance Operations in the future. Seven NATO nations (Canada, France, Germany, Italy, Netherlands, United Kingdom and United States) participated in this study.

Aim and Objectives

The “Urban Operations in the Year 2020” study aims to identify potential solutions that could develop the key urban operational capabilities for 2020. The specific objectives of the study [4] were the following:

- The description of the urban environment in the future (up to 2020);
- The construction of a conceptual framework for urban operations;
- The identification of the operational concepts that allow to conduct effective operations in an urban environment;
- The listing of the required urban operational capabilities for 2020;
- The identification of potential solutions that could develop the key capabilities.

Approach

In order to propose operational capabilities and the potential solutions to develop these capabilities, the study group adopted a staged approach (see Figure 2). It first identified a set of missions and tasks when conducting operations in an urban environment. Considering those missions, operational concepts were identified and classified into two categories: traditional and emerging concepts. The operational concepts provide a basis to identify desired military capabilities for operating in urban areas. The Capabilities Assessment Seminar (CAPS) was held in order to identify, assess and rank operational capabilities. Each of them was then

tested in a controlled Urban Seminar Wargame (USW) using two scenarios: a crisis response operation and a war-fighting situation. The USW led to the identification of potential solutions that could develop each capability.

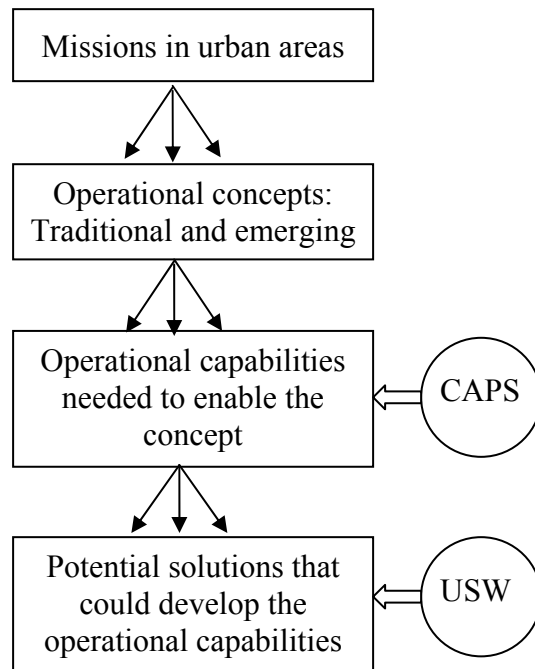


Figure 2: SAS-030 Approach to Develop Capabilities and Potential Solutions

Main Results

In order to identify and develop capabilities, the study group first reviewed the full range of urban missions and identified operational concepts that a NATO commander might employ to conduct each mission successfully. Nine general categories of missions were identified [4]. Of the nine missions, the study group considered the more general mission (Capture the urban area), which encompasses a sufficiently wide range of operational concepts.

These operational concepts fall into two general categories [4], a “traditional” group (siege, destruction, frontal assault) that would emphasise the *Engage* phase of USECT, and an “emerging” group (nodal isolation, precision strike, nodal capture and expansion, soft-point capture and expansion, segment and capture/isolate) that would emphasize the *Understand* and *Shape* phases.

These operational concepts provided a basis for the identification of desired military capabilities for operating in urban areas. The CAPS held in September 2001 resulted in a consolidated list of 42 operational-level

capabilities [4]. To allow for a more detailed examination of the most important capabilities, only 15 of them were designated as “key capabilities”. The main criteria used for this selection were the military significance and the extent of the capability gap.

Once key capabilities were identified, actions or potential solutions that could develop each key capability were developed and discussed during the Urban Seminar Wargame (USW). During this activity, twelve “System Concepts” that could provide the required capabilities were identified [4]. Specific representative systems were then examined in the Wargame and their military attractiveness, technical attractiveness, technical risk and research cost were assessed by the Study Group. Potential solutions were classified into the types of initiatives that might be taken and were separated into four categories: Doctrine, Organisation, Training and Materiel. Although more than half of the capabilities were driven by Materiel, a significant number had drivers in the areas of Doctrine, Organisation and Training.

The Study Group recommended that priority should be given to concept development and experimentation in order to determine potential solutions across all aspects of Doctrine, Organisation, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF) [4]:

- Doctrine: Develop NATO joint doctrinal guidance for urban operations;
- Organisation: Determine what organisational changes and new skill sets for personnel may be required;
- Training: Determine what enhancements to current training facilities and staff procedures are necessary to achieve an improved level of proficiency at operational level;
- Materiel: Exploit the USW results by initiating further research into technologies such as sensors, data fusion and non-lethal capabilities. Also, to initiate operational analysis and modelling & simulation to assess the benefits of emerging concepts and to monitor other scientific and technological research and development;
- Leadership: Include aspects of urban operations in professional military education programs;
- Personnel: Determine in conjunction with organisational change what expertise may be needed, such as linguists, judiciary and public utility specialists;
- Facilities: Determine requirements for Modelling & Simulation for training and operational analysis.

3.2 Non-Lethal Weapons Effectiveness Assessment (SAS-035)

SAS-035 is a NATO-RTO activity that was conducted from March 2001 to December 2004. This activity was initiated to develop a methodology for assessing Non-Lethal Weapon (NLW) effectiveness and to identify relevant MoEs. It is aimed that this methodology should support not only comparisons of one NLW against another but also against lethal weapons or other systems. Ten NATO nations (Belgium, Canada, Denmark, France, Germany, Italy, the Netherlands, Norway, the United Kingdom and the United States) participated in this study.

Aim and Objectives

The aim of the SAS-035 study is to improve NATO's ability to assess the effectiveness of NLWs across the full spectrum of crisis response and war-fighting operations. The specific objectives are the following [6]:

- Develop an appropriate methodology for determining Measures of Effectiveness (MoEs) and define specific MoEs for use in assessing the operational effectiveness of NLW systems;
- Determine military requirements deriving from various missions (different types of crisis response and war-fighting operations);
- Select promising examples of NLW systems based on mature technology and data availability;
- Identify and assess potential evaluation tools (national models, wargames or tools), and if appropriate use these evaluation tools to evaluate examples of NLW systems;
- Develop inputs for an 'effects' database using military and scientific judgement and drawing from existing national studies;
- Identify key capability gaps, requirements and issues.

Methodology

The SAS-035 methodology consists of developing a MoE¹ framework that uses both scenario-based information and system-related information to calculate measures of performance (MoPs²), response (MoRs³), system

¹ MoEs indicate the degree to which a target response satisfies a military requirement within an operational context.

² MoPs show how environmental factors influence weapon effects at the target.

³ MoRs indicate how a target reacts to a system's effects.

effectiveness (MoSEs⁴) and operational effectiveness (MoOEs⁵). More specifically, the methodology generates a number of objective outcomes using mathematical operations. The end result is a set of three MoEs calculated across seven dimensions, reflecting the effects on mobility, communications, physical function, sense and interpret, group cohesion, motivation, and identification. Figure 3 represents a schematic description of the SAS-035 methodology [6].

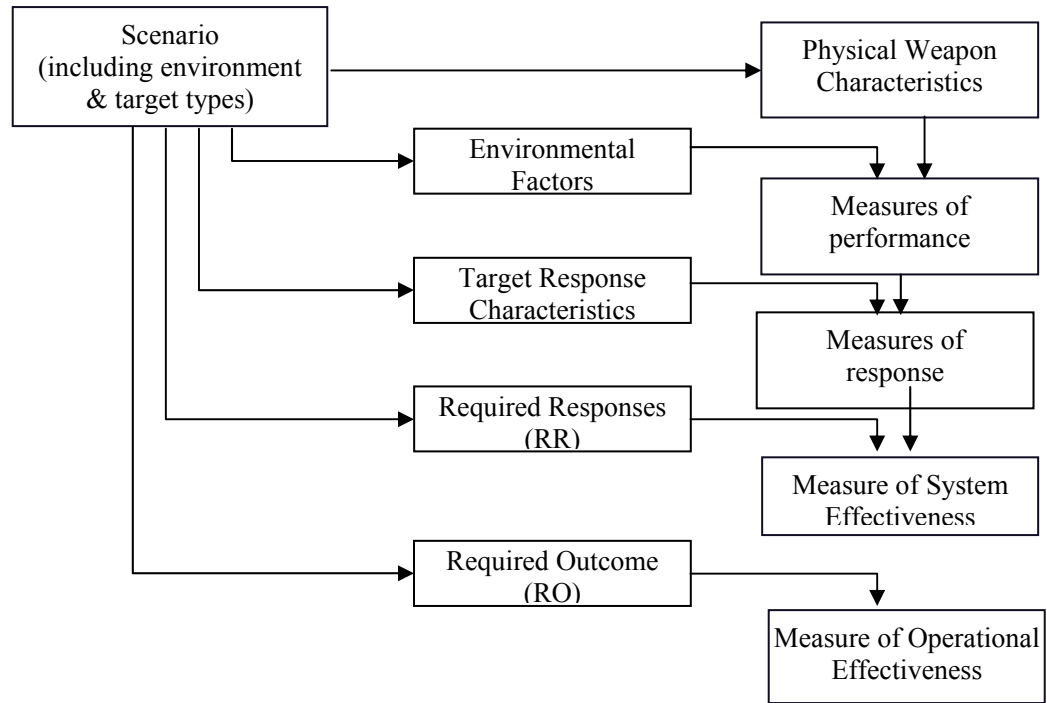


Figure 3: SAS-035 Methodology

The SAS-035 methodology could be applied across the various categories of NLWs: electromagnetic, chemical, acoustic, mechanical, etc. Furthermore, it can be applied for both personnel and materiel targets. The methodology enables calculation of the effectiveness of one weapon but it could be extended in the future to account for the use of more than one weapon, whether sequentially or concurrently. Finally, a significant inhibitor to the implementation of this methodology will be the lack of target effects/target response data, both human effects data and material effects data [6].

⁴ MoSE is a functional comparison between the Required Response (RR) and the Measure of Response (MoR) for a single weapon system used once, for a task in the scenario or mission of interest.

⁵ MoOE is a comparison between the Required Outcome and a number of MoSEs. It reflects the effectiveness of one or more lethal or non-lethal weapons used concurrently, sequentially, or repeatedly to achieve the Required Outcome.

3.3 Non-Lethal Weapons and Future Peace Enforcement Operations (SAS-040)

Held on November 17-21, 2003, SAS-040 is a NATO Multinational Exercise (MNE) on NLW that has been conducted in Bourges (France). This activity was organised in order to provide military planners with recommendations on the long-term planning for the use of NLW in peace support operations. Participating nations were: Denmark, France, Germany, Hungary, Netherlands, Sweden, Switzerland, United Kingdom and United States.

Aim and Objectives

The aim of the SAS-040 study is to answer the question: “How will operational staff carry out the full spectrum of peace enforcement operations in the 2020 timeframe using NLW, and which non-lethal technologies are the most appropriate and credible for such operations?” [7].

To achieve this aim, various experts (military, lawyers, technical experts, representatives of industry, etc.) were invited to take part in this MNE in order to consider the arising requirements, constraints and concerns in their respective fields.

Approach

The SAS-040 group study started by developing six scenarios covering a broad spectrum of likely future NATO operations. The considered scenarios were [7]:

- 1- Rescue operations at a critical site in urban terrain;
- 2- Threat of WMD in urban terrain;
- 3- Protection of key installations;
- 4- Crowd control at a food aid distribution point and checkpoint operation;
- 5- Protection and evacuation of a minority population;
- 6- Asymmetric threat.

These scenarios provide multiple operational contexts within which the application of future capabilities could be examined.

After the scenarios were developed, possible future non-lethal weapon technologies to be expected in the 2020 timeframe were described. Both anti-materiel/anti-infrastructure, and anti-personnel technologies have been considered [7]. The anti-materiel/anti-infrastructure technologies include electromagnetic technologies, chemical technologies, biological technologies and mechanical technologies. The anti-personnel technologies include electromagnetic technologies, chemical technologies, acoustic technologies, mechanical technologies, kinetic technologies and combined technologies.

More specifically during the MNE, efforts were done to assess which basic capabilities would be of highest likelihood, impact, and NLW relevance in the 2020 timeframe and which technologies would best match the requirements associated with these key basic capabilities. In addition, the legal and political implications and constraints associated with the use of non-lethal weapons in peace support operations were analyzed.

Main Results

Using the above-mentioned scenarios, SAS-040 identified five technologies/capabilities that best matched the requirements in the 2020 timeframe [7]: Radio Frequency (RF) devices⁶, Rapid barriers⁷ (acoustic, electro magnetic mechanical), Anti traction, Stun devices⁸ and Nets⁹. SAS-040 then compared operational requirements (range, onset time¹⁰, and duration¹¹) versus projected technology capabilities in 2020. The results of this analysis indicate if the technology is projected to meet (all, some or any) of the requirements for range, onset time, or duration across scenarios.

The analysis of legal and political implications and constraints associated with the use of non-lethal weapons in peace support operations indicates that there is an obligation to determine the legality of any new non-lethal

⁶ Radio frequency weapons produce a burst of energy, which damages the components of electronic systems or disrupts their operation.

⁷ Rapid Barriers Technology consists of deterring the passage of light or soft skinned vehicles and would be an appropriate means of rapidly erecting a manned barricade. It could also be used against people (e.g. acoustic)

⁸ Stun devices are intended to incapacitate an individual without excessive force by discharging a high voltage/low amperage electric charge to the individual. The effect is a timely distortion of the nerve system. Systems could have different shapes, e.g. baton (direct contact), or pistol (firing metal darts connected with wires).

⁹ The deployment of Nets allows the arresting of moving vehicles, small groups and individuals as well as deny access to some areas or assets. This may be achieved via the deployment of wires or fibres.

¹⁰ The onset time is the maximum time between triggering the NLW and the occurrence of its desired effect.

¹¹ Duration corresponds to the duration of the effect of a “single shot” of a NLW.

weapons. Moreover, there is no legal obligation to resort to non-lethal force when lethal force is authorised. In fact, NLW will continue to be complementary to (and will not replace) lethal weapons [7].

The main recommendations of SAS-040 were:

- To invest in R&D programmes on Radio Frequency, Stun Devices, Anti-traction, Rapid Barriers and Nets in order to satisfy key 2020 military requirements.
- To determine whether current Law of Armed Conflict (LoAC) adequately addresses the use of NLW.
- In order to comply with their obligation to determine the legality of new weapons, states should aim to collect sufficient and reliable information about the effects of NLW.
- In order to ensure that NATO forces retain the ability to accomplish missions, NATO nations must remain vigilant against the development of specific legal regimes which unnecessarily limit the ability to use NLW.

3.4 Human Effects of Non-Lethal Technologies (HFM-073)

HFM-073 is a NATO-RTO activity that was conducted from April 2001 to May 2005. This activity was initiated to assess effects of NLWs on individuals and populations. Nine NATO nations (Czech Republic, France, Germany, Netherlands, Norway, Poland, Sweden, United Kingdom and United States) participated in this study.

Aim and Objectives

HFM-073 aims to address the human effects of Non Lethal Technologies (physiological & psychological) [8] to:

- Assess the consequences of NLWs for health and safety;
- Increase information exchange to facilitate understanding & reduce redundancy;
- Identify knowledge gaps and research needs;
- Supply relevant information to commanders/warfighters and suppliers;
- Facilitate public acceptability;

- Identify non-lethal weapons suitable for anti-terrorist activities especially when non-combatants or innocent bystanders are involved, with special attention given to safety margins.

Main Results

HFM-073 considered the technologies being used for non-lethal applications and discussed the expected desired and undesired human effects of each of them. The reported technologies are: radio frequency, light/lasers, electrical stimulation devices, kinetic devices, acoustic devices, multi-sensory devices, chemical and physical devices. Prioritized recommendations for needed human effects data were provided. The study group also defined terms that are most relevant to the human effects of NLWs in order to have a common glossary of NLW terms.

The main conclusions of this study were that NATO operations will benefit by having a NLW capability and that information on the human effects of the NLW technologies is critical to all aspects of a NLW capability: concept, development, evaluation, testing, policy approval, acquisition, deployment, and rules of engagement. A particular need appears also for acquiring data on promising, novel technologies, such as those using electromagnetic or electrical stimulation.

The study group recommended actions to gain acceptance of NLW use by military members and the general public. They proposed that the general concept of the value of NLW should be addressed and stated that information on human effects will be of major importance. They also proposed to launch a new Exploratory Team on the Human Effects of Emerging Non-Lethal Technologies such as radio frequency, laser, and electro-muscular devices. These technologies have a tremendous potential for effectiveness, but are difficult to test because of medical ethics and conservative occupational health and safety standards. The study group outlined also the legal and political issues due to the fact that within the NATO nations different laws are applied in different situations. There is then a need to develop a common NATO standard for the use of NLW and training of personnel. Finally when using NLWs, aspects related to medical preparation and planning for immediate rescue activities and therapeutic strategy are essential and should be well prepared.

3.5 Command Centre Challenges for Urban Operations (IST-046)

IST-046 is an ongoing NATO-RTO activity that has started in January 2004 and which is planned to be completed by December 2006. This activity was initiated after the *SAS-030 Urban Seminar Wargame* [4] indicated that the availability of information and knowledge through a fully integrated Command Centre system is an essential resource, and a key asset toward an *Understand* capability. The aim of this activity is to examine how C2 processes in urban operations can be improved by emerging Information Technologies (IT). Five NATO nations (Canada, France, Germany, Netherlands and United States) are participating in this study.

Aim and Objectives

IST-046 aims to examine how C2 processes in urban operations can be improved by emerging Information Technologies (IT). The specific objectives [9, 10, 11] of this study are the following:

- Establish all Information Requirements (IR) for battalion-level and below;
- Identify which IR cannot be supported with the current doctrine, organisation, equipment, personnel and training;
- Make an inventory of the technologies that might be relevant for the shortcomings;
- Develop conceptual solutions as a result of the preceding activities;
- Organize a workshop/specialist meeting to discuss the subject of C2 in Urban Operations;
- Develop a concept demonstrator considering one relevant shortcoming and one potential IT solution.

Approach

The IST-046 approach (Figure 4) starts by formulating all IR during the planning and conducting of an operation in urban terrain. Then, shortcomings for inventoried IR are identified. As a result, a prioritized list of Critical Information Requirements (CIR) is established. Afterwards, the current and future development in IT that might be relevant for the shortcomings are inventoried and concept solutions are developed. Finally,

the major results of this activity will be illustrated. A final report as well as a movie clip and a demonstrator of one proposed concept solution will be produced.

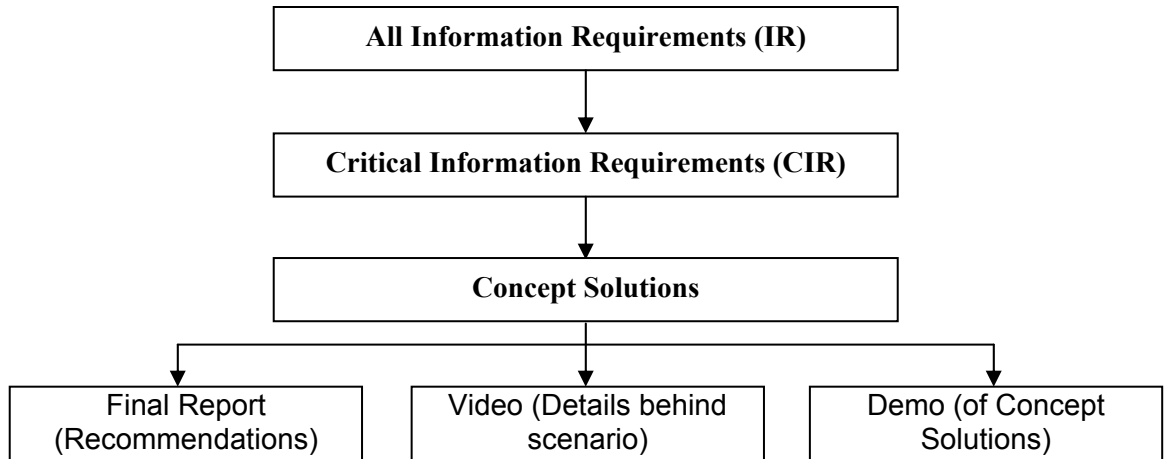


Figure 4: IST-046 Approach

Preliminary Results

The study group members first identified all IR during the planning and conducting of an operation in urban terrain, at the battalion, company and platoon level. More specifically, they created a common list of IR based on a scenario in which the participating nations have defined the basic assumptions for several topics related to the doctrine, tasks and C2 processes. This scenario was prepared and adapted from *Urban Challenge*, originally created by the Directorate of Land Strategic Concepts of Canada. Three vignettes were designed and exploited to illustrate the range and complexity of urban operations [13]: a crisis response operation, a defensive operation and an offensive operation. A 5-days wargaming exercise was conducted with military experts from Canada, France and Netherlands [14]. A collaborative working environment was used to enable each participant to provide ideas and concepts in coordination with the other members of the team. From the wargaming exercise, about 400 IR were identified and grouped into categories.

For each of the inventoried IR, the study group assessed how critical the information is, what is the minimal quality required, how dependant on information quality is operational performance and “how bad it is” nowadays. Depending on the assessment results, a prioritized list (CIR) was established [15]. Fifteen IR were considered as critical. In particular,

the CIR *-Blue Force Tracking-* has been detailed and considered for the development of a concept solution.

The CIRs, in a priority order, are:

Most critical

- 1- Blue Force Tracking;
- 2- Mapping of the city;
- 3- Red Force Tracking;
- 4- Dynamic Route planning (vehicles, soldiers);
- 5- RT Surveillance of objectives, of routes of approach;
- 6- Communications (coverage map, testing);
- 7- Culture and social visualization (symbolic non-physical information);
- 8- Buildings layouts for objectives;
- 9- Foe discrimination;
- 10- Prediction of adversary actions;

Less critical

- 11- Identification of sites which may be centers of gravity;
- 12- Request for support;
- 13- Performance analysis of capability (sight, weapon systems, etc.);
- 14- Identification of people and equipment in RT;
- 15- Graphic and verbal situation reports.

The study group made an inventory of the current and future C2 Information Technology (IT) developments that might be relevant for the identified shortcomings [16]. The IT survey included existing systems, prototypes, as well as studies or ideas on more prospective solutions. Recently, the study group was determining the Technology Readiness Level (TRL) of each of them and was working on the link between these technologies and the CIR previously identified [17, 18]. The participating members are expected to produce a list of potential current and future developments in IT that can potentially solve the shortcomings and a list of national developments in this area. Finally, to illustrate the major results of IST activity, one concept solution as well as one movie clip are being produced. Also, a report that describes the work carried out and the envisioned solutions will be written.

3.6 Sensors Requirements for Urban Operations (SET-076)

SET-076 is an ongoing NATO-RTO activity that has started in June 2003 and which is planned to be completed by December 2006. This activity was initiated to investigate sensors requirements in urban operations. Based on previous studies, which looked at identifying the requirements in terms of information, capabilities and technologies and at current shortcomings in meeting these requirements when dealing with urban operations, SET-076 addresses more specifically sensor requirements and the shortcomings and limitations of existing sensor technologies. Six NATO nations (Canada, France, Germany, Netherlands, United Kingdom and United States) are participating in this study.

Aim and Objectives

SET-076 aims to identify the fundamental limitations associated with various sensor types when deployed in urban areas and to propose future research topics and collaborative assessment or demonstration activities. The specific objectives of this study are the following [19, 20]:

- Define the sensing problems posed by operations in urban environments;
- Identify likely shortcomings in current sensing capability, and predict likely sensor technology developments in the near future;
- Recommend research areas to address the sensing requirements identified by studies such as Land Operations 2020, Urban Operations 2020 (SAS-030), and various other national studies;
- Provide guidance on overcoming the limitations of sensors that have a potential to be used in urban/complex terrain;
- 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.

Approach

The study group adopted with some modifications the IST-046 results, as well as the vignettes of IST-046. The following methodology [21] is considered:

- a. Enhance Scenarios/Vignettes provided by IST-046 to better reflect sensing challenges in urban operations;

- b. Identify likely current sensor limitations by going through capabilities for each mission profile;
- c. Get feedback from users;
- d. Identify shortcomings of existing sensors;
- e. Discuss and identify technology being developed to address those shortcomings;
- f. Recommend list of future technologies with a focus on what could be fielded in the next 5-10 years.

Preliminary Results

First, the team decided to group the capabilities presented by IST-046 into categories [22]. Thus, from IST-046 results, various CIRs were consolidated into categories that better reflect the sensors requirements (Table 3).

Then, the study group examined technologies potentially able to provide the needed capabilities [23]. A worksheet was prepared to be filled in for each potential technology concept. The worksheet includes the list of IR that are addressed by the technology, a drawing picture, a short description, performance, size, cost, maturity, concept of operation and limitations. The team plans to fill out the technology worksheet before evaluating and ranking the sensors technologies.

Table 3: Capabilities Categories Defined by SET-076

Category	Description
Other Study	Not a sensor requirement. Need will have to be addressed elsewhere.
Mapping Facilities	Find, geo-locate, and identify facilities.
Mapping Utilities	Find, geo-locate, and identify utilities
Mapping Routes	Find and geo-locate roads, subway systems, underground motorways, etc.
Identification	Identify personnel, vehicles, and equipment – Is it a T72 or an M1?
Classification	State object class – Is it a tank or a truck? Is it a tree or a person?
Detection	Find “stuff” on the battlefield. This could be anything from military forces to civilian assemblies.
Tracking	Know where an item has moved to. Keep track of it.

A workshop is planned in May 2006 (SET-090) to evaluate the proposed technologies for sensors. This workshop will bring together technical experts and military users to evaluate the emerging sensors technologies [24]. The outcome of this workshop is expected to be a report, which will identify the most promising sensor technology areas for urban operations, as well as the urban operations sensor requirements that are the least addressed. It will also include proposals for completing the SET-076 study objectives.

3.7 Urban Sensors Exploratory Study (TTCP-SEN-AG9)

TTCP-SEN-AG9 is an ongoing TTCP activity that has started in February 2004 and which is planned to be completed by June 2006. This activity was initiated to investigate sensor capabilities and technology requirements and to recommend priorities for sensors investment. Four TTCP nations (Australia, Canada, United Kingdom and United States) are participating in this study.

Aim and Objectives

TTCP-SEN-AG9 aims to investigate sensor capability requirements and to assess technology readiness to answer these requirements. The specific objectives of AG 09 [25, 26] are the following:

- Report on sensor capability requirements;
- Consider technology maturity and readiness to meet these requirements;
- Develop a road map to take these technologies forward;
- Recommend priorities for investment.

Let us note that TTCP-SEN-AG9 and SET-076 NATO-RTO groups have comparable objectives. To avoid duplication of efforts, SEN-AG9 suggested that joint meetings be held to establish core issues common to both parties and to work together on common tasks.

Approach

The study group working methodology is the following [25, 26]:

- a. Conduct a review of military users' IR in the urban environment;

- b. Create a subset of those IR that, potentially, can be met using sensor technology;
- c. Populate a Task/Technology matrix database (including information from relevant national programmes);
- d. Produce an initial report on sensor capability requirements and an assessment of technology maturity and readiness;
- e. Develop road map to take technologies forward;
- f. Recommend priorities for investment;
- g. Recommend areas that would benefit from cooperation between nations;
- h. Maintain a high-level technology watch.

Preliminary Results

The study group started by identifying military users' IR that can be met potentially using sensor technology. The group members compared the AG9 list of requirements with those generated by the SET-076 group and concluded to a very good agreement. Among the preliminary results, there was the categorization of the user IR at the top level into sensor requirements related to environment, indigenous population and enemy. In addition, the requirements within each of these top level categories were grouped into the following sub-categories: mapping, reconnaissance, surveillance, identification and intelligence [27].

A requirements/technology matrix was filled in with near, mid and long-term technologies. In particular, the group started to colour-code the maturity of each of the sensor systems suggested for each requirement. The upcoming actions will evaluate the highest priority requirements in order to start the process of developing a roadmap for research of the top five priorities.

3.8 Non Lethal Weapons (TTCP-WPN-AG 17)

TTCP-WPN-AG17 was conducted from 1997 to 2002 to investigate promising NLW technologies and assess their psychological effects. Four TTCP nations (Australia, Canada, United Kingdom and United States) participated in this study.

Aim and Objectives

TTCP-WPN-AG17 aims to investigate promising NLW technologies and areas of possible collaboration in addition to assess the psychological effects of those NLWs. The work conducted by AG17 was done in two separate phases. The specific objectives of each phase are [28]:

Specific Objectives of Phase 1

- Identify promising NLW technologies and areas of possible collaboration through information exchange;
- Nominate technological areas where collaboration would be of mutual benefit.

Specific Objectives of Phase 2

- Arrange a joint WPN/HUM/JSA workshop to investigate and assess the optimum psychological effects that can be exploited by NLW technologies;
- Co-ordinate an interim review of member nation's policies, political intentions and views on low collateral damage of NLWs.

Main Results

In the first phase and after a review of national NLW programs, the participating nations provided an agreement of collaboration for the following areas [28]:

- a. Because there was no central registry on the effects of NLW technologies and in order to avoid duplication of work, it was proposed to collaborate in the preparation and distribution of a national bibliography of the effects of NLW technologies;
- b. It was agreed that high fidelity simulation of NLW effects is difficult because of the lack of objective data and conversely, the data is difficult to obtain because NLW effects cannot be realistically simulated. Thus, it appears important to improve Modeling and Simulation (M&S) tools that could be used to measure the operational effectiveness of NLWs;
- c. As different countries might have different interpretations of safety and health regulations concerning the use and the experimentation with NLWs, an area of collaboration could consist of the identification of

national minimum NLW safety thresholds related to health and safety standards;

- d. Another specific area of collaboration might be the investigation of the acoustic effects on inanimate surrogate targets, and general vehicle stopping technologies. But after analyzing this possibility, it was concluded that there was no sufficient basis for collaboration in both these areas.

The second phase of AG 17 consisted of a short review of the national views on low collateral damage of NLWs and then, the conduct of a Joint Workshop bringing together representatives from the WPN, HUM and JSA Groups, on the psychological effects of NLWs. More specifically, the aim of the Workshop was to investigate the psychological effects of non-lethal weapons, to assist in understanding the operational effectiveness of non-lethal technologies. The major findings reached in the workshop are the following [28]. First, a table of factors or emotions that could be exploited to attain a military objective was prepared through structured brainstorming sessions by an international group of psychologists and weapon developers. Second, the Workshop participants concluded to the pressing need for a psychological theoretical framework to provide a scientific basis for the study of the psychological effects of NLWs. Finally, TTCP-WPN-AG17 recommended that a Joint HUM/WPN action group be formed to identify Non-Lethal physiological and psychological counter personnel incapacitating effects and the means of delivery of these effects. Collaborative R&D projects on personnel incapacitating effects delivery were equally recommended.

3.9 Research Design for the Assessment of Non Lethal Weapon Human Effects (TTCP-HUM-AG22)

TTCP-HUM-AG22 is an ongoing TTCP activity that has started in September 2003 and which is planned to be completed in fall 2006. This activity was initiated to determine a set of research designs for gathering psychological and physiological data on target responses to counter-personnel NLWs. Four TTCP nations (Australia, Canada, United Kingdom and United States) are participating in this study.

Aim and Objectives

TTCP-HUM-AG22 aims to determine internationally accepted standardized test metrics and research protocols (which reflect ethical and legal constraints) for the assessment of NLW human effects. The specific objectives of AG 22 [29] are the following:

- Select the target responses to be investigated;
- Recommend appropriate test metrics for the response characteristics;
- Develop research options for selected technologies;
- Identify and apply approved human research ethical boundaries for the developed options;
- Recommend research protocols for the standardized assessment of NLW human effects.

Preliminary Results

After two iterations, a research design approach was identified (Figure 5). Based on this design approach, each nation was assigned a specific NLW (blunt trauma, flash bangs) and has identified target responses and the corresponding metrics as well as the weapon effects and their metrics. Then, the AG made a common agreement on those metrics and results. In parallel, the ethical boundaries that might constraint the research designs for the specific NLWs were being addressed. To complete this study, the AG will incorporate lessons learned from the human research ethical review and produce an example of an experimental design for the collection of selected NLW human effects.

In addition, to overcome the lack of an internationally agreed handbook on the conduct of NLW human effects R&D, the AG decided to produce a scientific handbook on the design of NLW human effects experiments and protocols. The report will include:

- a description of the nature of data to be gathered and the complexity involved in its collection;
- the process for establishing an experimentation design for the assessment of NLW human effects;
- An example of an experimental design that illustrated the application of the thought process and provided the rationale for the particular design selected; and
- a description of the human research ethical issues and constraints applied to the experimentation design.

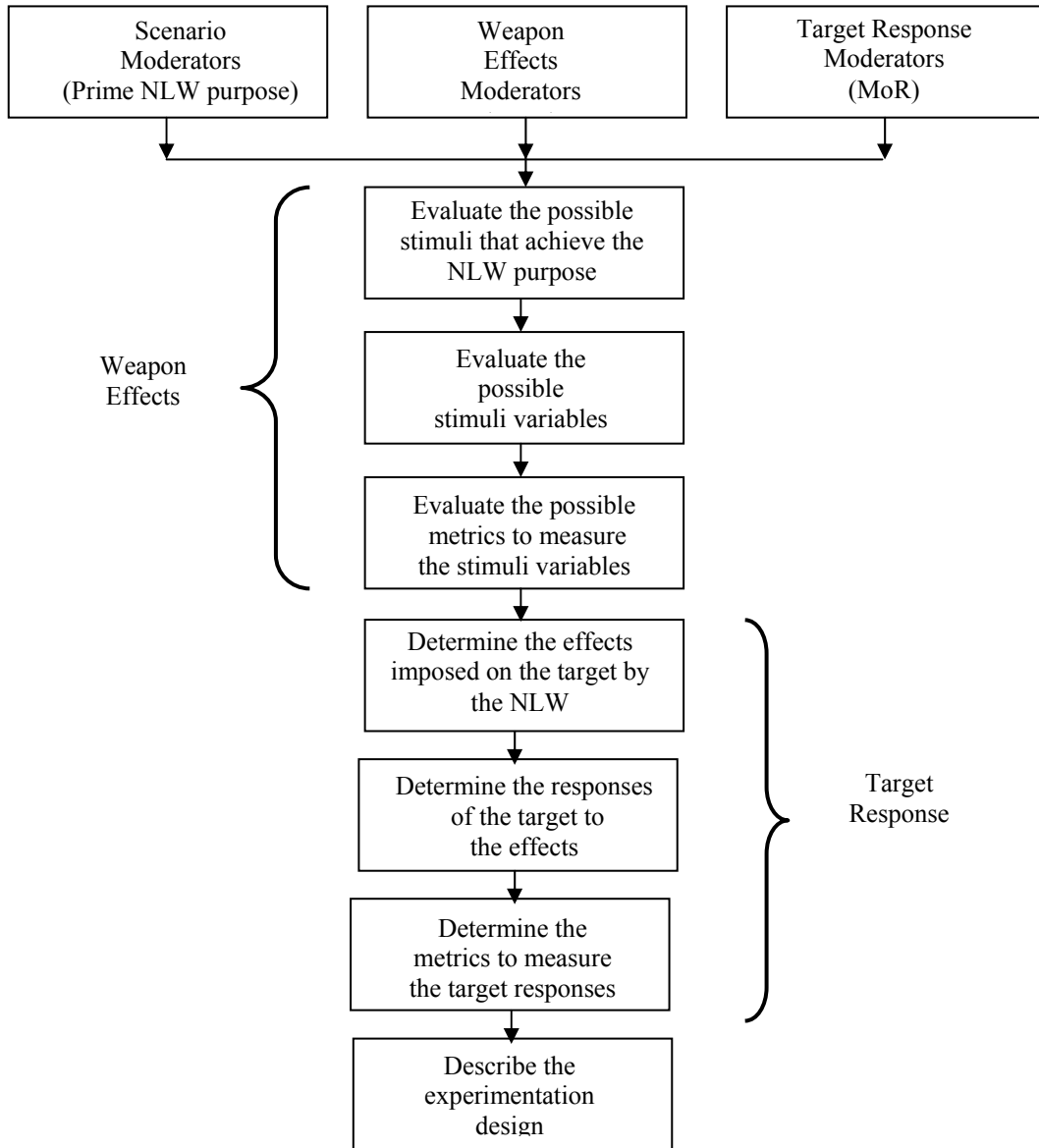


Figure 5: AG 22 Research Design Approach

3.10 ABCA Quadripartite Advisory Publications

In this section, an outline of the ABCA Quadripartite Advisory Publications (QAP) that addressed subjects related to urban operations will be provided.

QAP 273: Concepts for Urban Operations

QAP 273 [30] identifies a common concept for urban operations which allows ABCA Armies to understand each other when discussing interoperability. The concept consists of achieving mission success throughout the spectrum of conflict by Find/Assess, Fix/Shape and Strike/Dominate the enemy throughout the operation:

- 1- FIND/ASSESS. Analyse the battlespace in order to locate the enemy's critical nodes/decisive points while developing precise and timely situational awareness that is tailored to the urban environment.
- 2- FIX/SHAPE. Restrict the enemy's freedom of action and manoeuvre with the view to breaking his will and cohesion.
- 3- STRIKE/DOMINATE. Simultaneous or sequential operations as appropriate using overwhelming force, both lethal and non-lethal that include close combat operations when necessary.

In order to implement this urban operations concept, QAP 273 identified the following areas that would need to be studied: doctrine, tactics, equipment development, training and organizational development. More specifically, the following themes were considered important: C4ISTAR/C4ISR/Combat ID, survivability, precision fires, precision manoeuvre, non-lethal effects, non-combatants, information operations, FP, sustainability, policy, training and doctrine, leadership, simulation and ground integration.

QAP 319: Agreeing Capabilities Required to Implement the Common Concept for Urban Operations

QAP 319 [31] identified the capabilities required by the ABCA Armies for the implementation of the common concept for urban operations. The identified capabilities are not intended to replace existing capabilities but rather to augment them. The proposed capabilities were grouped into the following functions: manoeuvre, doctrine, fire support, mobility, intelligence, communications, information and combat service support.

QAP 274: Delivery of Urban Operations Capabilities

The delivery of capabilities required to implement the concept for urban operation can be initiated by addressing equipment, structures, and training issues. QAP 274 [32] addressed specifically those issues that have been identified as critical: equipment (mobility, C2, effects and ammunition types, ISTAR), structures (liaison officers, organic effects) and training (basic, collective, simulations).

QAP 320: Interoperability Issues in Urban Operations

Upon development of a common concept for urban operations, and the understanding of the required capabilities, QAP 320 [33] tackled the interoperability issues in urban operations. A wargaming seminar and directed brainstorming sessions were organized to elicit the critical interoperability issues. The identified interoperability issues are related to the following aspects: manoeuvre, fire support, mobility, counter mobility, survivability, intelligence, C4 and combat service support.

QAP 304: Fire Support in Urban Operations

In the former list of interoperability issues, fire support was selected to be studied in QAP 304 [34]. The aim of this QAP is to identify the implications of conducting fire support operations in an increasingly urbanised environment. This publication addressed the direct and indirect fire weapon strengths, weaknesses and effects in urban areas. As a result, it was concluded that successful operations require having the widest possible range of weapons capabilities available, so that the most appropriate mix would be applied as the circumstances dictate. It was also concluded that fire support should be carefully deployed. On one hand, significant use of indirect fire systems, very large calibre munitions or area weapons can degrade the operational environment and provide obstacles to ground forces. On the other hand, it seems that the use of man-portable weapons and effective direct fire supporting systems with the commitment of trained infantry, would be the most certain and direct method to successfully conduct urban operations without unnecessary damage and civilian casualties.

3.11 Joint Urban Warrior 2004

Held on March 21-26, 2004, Joint Urban Warrior 2004 (JUW04) was the first U.S. Marine Corps and U.S. Joint Forces Command (USJFCOM) cosponsored wargame under the Joint Urban Warrior program of events, including workshops, seminars, and planning conferences. The JUW04

regrouped more than 150 participants from the five branches of the military, the intelligence community, non-Department of Defence agencies and organizations, and multinational coalition partners from eight countries. The foreign delegations represented Australia, Canada, Finland, France, Germany, Netherlands, Sweden, and United Kingdom.

Aim and Objectives

JUW04 aimed to integrate advanced operational concepts, organizational innovations, technologies, and other transformational opportunities within the complex operations of the “three-block war”. The paradigm of the “three-block war” emphasizes the simultaneous conduct of combat, stabilization, peacekeeping and humanitarian relief operations in a major urban environment. The specific objectives of the wargame were [35]:

- To develop innovative operational and organizational concepts, approaches and structures used to conduct major joint urban operations;
- To identify desired effects and indicators of success in joint urban operations;
- To assess and refine the joint urban operations developed concepts;
- To identify issues of particular interest to homeland security.

Scenario of the wargame

The JUW04 considered a specific scenario, which considered a capital city of a strategically important nation whose government was threatened by internal instability, by local and international terrorism, and by rebellious military forces. The scenario provided a wide range of variables that involved the full spectrum of national power, diplomatic, information, military and economic options [35].

Main Results

First, it was concluded that the effects-based planning process is viable in the urban environment and should be used in future urban experiments. It was also apparent that a detailed information operations plan for the urban fight is essential to gain the trust and confidence of the population. In addition, a logistic preparation of the battlefield is needed to fully understand the key infrastructure and facilities in the urban area, including humanitarian assistance, disaster relief and FP. Also, persistent and pervasive intelligence, surveillance, and reconnaissance are important capabilities that require more work. Other areas that would also require

attention include professional military education courses in the urban environment, measures of effectiveness and rules of engagement for the urban battle.

3.12 Joint Urban Warrior 2005

The Joint Urban Warrior 2005 (JUW 05) wargame was conducted 21 – 26 May 2005. More than 290 representatives from the five US Services, NATO, non-Department of Defence agencies and organizations, and multinational partners from eight countries participated in JUW 05. The multinational delegations represented Australia, Canada, France, Germany, Netherlands, Sweden and United Kingdom as well as international students representing the Command and General Staff College.

Aim and Objectives

JUW 05 aimed to provide insights into Joint Urban Operations, including stability operations and humanitarian assistance, non-lethal weapons, flexible and adaptable ISR capabilities and a need for further experiments. According to [36], the core objectives for JUW 05 were the following:

- Continue to develop “Political End State Planning First” as the driving factor in Joint, Combined, and Interagency Urban Campaign planning and execution in the context of the Three Block War.
- Identify key issues & explore processes to plan and conduct campaigns against enemies operating in a major urban area.
- Building on the findings and issues developed in Joint Urban Warrior 04, continue to explore, develop, and assess innovative operational, organizational, and command relationship approaches for the conduct of Joint, Combined, and Interagency Urban Operations.

Scenario of the Wargame

The JUW05 Scenario was based on Operation Iraqi Freedom (OIF), in the city of Baghdad with a ground truth date of 13 APR 03 (i.e. after the initial fighting). The environment was considered to be semi-permissive with growing criminal and civil unrest. The following factors aggravate the situation in Baghdad: less than 50% of houses have drinking water or electricity; emergency services are not operating and over 50% of the population is less than 21 years old and provides a recruiting pool for insurgents.

Main Results

It was concluded that a lack of common language or understanding of operational terms among multinational partners persists. Moreover, professional military education and training must ensure that military doctrine and theory is taught correctly and consistently to ensure common understanding. The key components of this effort include doctrine, information operations, effects, FP, center of gravity, conflict resolution, and conflict termination.

Concerning current capabilities and assets, it was concluded that current intelligence collection, assessment, production, and dissemination assets are insufficient to meet the demands or expectations of forces operating within a complex urban environment. In addition, it was concluded that current military operations lack the capabilities to isolate insurgent forces from the population and to control the infrastructure of a major city. It was also found that current FP demands create operational paralysis and negatively impact information operations, which continue to be misunderstood. Another finding was that agility, both mental and physical, must become a feature of effective combat forces, congruent with manoeuvre, flexibility, and lethality.

It was also concluded that a better understanding of the capabilities and limitations of the US Joint Interagency Coordinating Group (JIACG) by military personnel is required. Moreover, there is a requirement to establish tactics, techniques and procedures for collaboration and planning across the entire interagency process.

4. Potential Future International Research Activities

The literature review revealed two main types of research activities. Research activities in the first category (i.e., SAS-030, QAP-273, QAP-274, QAP-319 and QAP-320) address the subject of urban operations at a higher level, attempting to provide a general view covering all or most stages within the USECT framework. Research activities in the second category (i.e., SET-076, SET-090, TTCP-SEN-AG9, IST-046, QAP-304) have a narrower focus, addressing only some of the operational tasks associated to some of the stages in the USECT model and they do so at a lower level, attempting to provide a closer view of the subject being considered.

In Table 4, the higher level activities are the “vertical” ones, while the lower level activities are the “horizontal” ones. The higher level activities are matched with the column “USECT phases”, while the lower level ones are matched with the column “Operational Tasks”. More precisely, if a given research activity such as SET-076 for example, which is dealing with sensors, is associated in the table with several operational tasks (such as C4ISR and Space Operations in this case), it means that this activity tackles *some* aspect involved in each of the operational tasks (in this case the sensor aspect), and not *all* aspects characterizing these operational tasks. In terms of the lower level activities, four issues have been addressed within the activities that were reviewed in this paper: sensors, non-lethal weapons, C4ISR and Fires.

All other issues, which could also be regarded either at a higher level or at a lower level, could be considered potential candidates for future research. In terms of Table 4, all the empty spaces represent subjects that were not addressed at all, at least within NATO-RTO, TTCP and ABCA research organizations. The non-empty spaces were generally *partially* addressed, meaning that more research is still possible even for the non-empty spaces.

Among the numerous issues that could potentially benefit from a concerted international research effort, three were selected by the authors as prime candidates for initiating such an effort (sections 4.1, 4.2 and 4.3). The reasons behind this selection were two: the high importance of the issue, as perceived by the authors, towards achieving success when conducting an urban operation, and the fact that the subject was not tackled before within the research organizations considered in this study. Upon lecture of a preliminary version of this document, members of the TTCP Joint Systems and Analysis (JSA) Group notified the authors about three additional areas that were of particular interest to them (sections 4.4, 4.5 and 4.6).

Table 4: Literature Review Results

USECT PHASES	OPERATIONAL TASKS	INTERNATIONAL RESEARCH ACTIVITIES
UNDERSTAND	C4ISR	SET-076, SET-090, TTCP-SEN-AG9 (Sensors), IST-046 (C2)
	Space Operations	SET-076, SET-090, TTCP-SEN-AG9 (Sensors)
	Special Operations	
SHAPE	C4ISR	SET-076, SET-090, TTCP-SEN-AG9 (Sensors), IST-046 (C2)
	Space Operations	SET-076, SET-090, TTCP-SEN-AG9 (Sensors)
	Fires	SAS-035, SAS-040, HFM-073, TTCP-HUM-AG22, TTCP-WPN-AG17 (NLW), QAP-304 (Fires)
	Civil-Military Operations	
	Special Operations	
	Information Operations	
	Psychological Operations	
	Movement and Manoeuvre	
	Logistics Support	
	Force Protection	
ENGAGE	C4ISR	SET-076, SET-090, TTCP-SEN-AG9 (Sensors), IST-046 (C2)
	Space Operations	SET-076, SET-090, TTCP-SEN-AG9 (Sensors)
	Fires	SAS-035, SAS-040, HFM-073, TTCP-HUM-AG22, TTCP-WPN-AG17 (NLW), QAP-304 (Fires)
	Civil-Military Operations	
	Movement and Manoeuvre	
	Special Operations	
	Information Operations	
	Psychological Operations	
	Logistics Support	
	Force Protection	
	Personnel Recovery	
	CONSOLIDATE	C4ISR
Space Operations		SET-076, SET-090, TTCP-SEN-AG9 (Sensors)
Civil-Military Operations		SAS-035, SAS-040, HFM-073, TTCP-HUM-AG22, TTCP-WPN-AG17 (NLW)
Logistics Support		
Special Operations		
Psychological Operations		
Force Protection		
Consequence Management		
Personnel Recovery		

QAP-273, QAP-274, QAP-319, QAP-320

SAS-030

TRANSITION	C4ISR	SET-076, SET-090, TTCP-SEN-AG9 (sensors), IST-046 (C2)
	Space Operations	SET-076, SET-090, TTCP-SEN-AG9 (Sensors)
	Civil-Military Operations	SAS-035, SAS-040, HFM-073, TTCP-HUM-AG22, TTCP-WPN-AG17 (NLW)
	Logistics Support	
	Special Operations	
	Force Protection	
	Consequence Management	
	Personnel Recovery	

Six topics, presented in the following sections, were retained as good potential candidates for future research: logistics support, human factors issues, movement and manoeuvre, asymmetric force protection, special operations and interaction with non-governmental organizations.

4.1 Logistics Support

The nature of urban operations creates unique challenges in terms of logistics support. One of the factors that can potentially create such challenges is the complexity of the physical terrain in urban areas. The presence of buildings may mean that supplies need to be delivered on several floors of a building, and sometimes manhandled up the stairwells, which may lengthen the delivery time and may make the distribution more complicated. The evacuation of the wounded can also be made more difficult, for the same reasons. Another challenging factor is the presence of large number of non-combatants that might also get wounded or be in need for food supplies, which will create an additional burden for medical or supply services. The quantities of materiel needed are likely to be different (higher) in urban operations from other types of operations, and the same is true for the type and amount of medical services required. The fact that troops are likely to operate in small groups which might be distributed all over the city also complicates the delivery process. More trips will be necessary to respond to the demand, and also a better mechanism of keeping track of the type and amount of support required by the various groups, as well as of their most current geographical positions. It should also be noted that logistics support is needed in most phases of the USECT framework and it may be of special importance during the *Transition* phase.

Based on the literature review conducted for this study, it appears that the subject of logistics support in urban operations did not receive a significant

amount of attention from the part of analysts or researchers. At most, the issue was acknowledged as a difficult one and some of the expected challenges were reviewed, but, to the authors' knowledge, there was no systematic effort to address the issue in a holistic manner. It is the authors' opinion that it could be of significant value to address the problem in its entirety, from a clear definition of the logistics requirements in urban operations, up to the proposal of solutions to respond to those requirements. Depending on the time available, the scope of such a study could be narrowed to tackling the logistics issues that are specific to a particular phase in the USECT model (such as *Engage*, for example), or it could be subsequently enlarged over all phases in USECT where logistics support is expected to play a role. A wide range of deliverables could be considered depending on the direction the study may take, from routing algorithms, for example, to checklists or handbooks.

4.2 Human Factors Issues

The human dimension is one of the most important issues in urban operations. This is no surprise, since the soldier remains central in any combat system. However, in urban operations, the challenges related to the human issues are even further augmented because of several factors that are only specific to this environment. One of those factors is the fact that operations in urban terrain usually result in more injuries/casualties than operations conducted in a different setting. This creates a particularly stressful environment for the soldiers, which may influence their level of fatigue or their morale. An additional factor is, again, the presence of non-combatants and the possibility that some of the enemies might hide under a non-combatant appearance. The troops need to be able to deal with the non-combatants and at the same time cope with unfamiliar surroundings and a different cultural environment. They may also have to cope with less than perfect logistics support, as well as with failures in the communication network, which may leave them in situations in which they lack supplies or they have a poor situational awareness.

Once again, based on the literature review carried out for this study, it appears that relatively little effort was spent on addressing human issues when compared to the effort spent on addressing materiel issues. Examples of subjects that could be tackled within this vast domain of human factors include the following: identify the types of skills that are needed to be able to deal with the specific features of the operations in urban terrain; identify the type of training that is required to ensure the soldiers are fully prepared to deal with the difficulties associated with operating in an urban environment; analyze organizational issues and current or proposed rules of engagement, through modeling and simulation; analyze the

interoperability between different armies in all aspects that pertain to personnel (communication between soldiers, compatibility or complementarity of the various rules of engagement, etc.) and analyze the human performance issues in urban military operations. Once again, depending on the time available, the scope of such a study could be made narrower or larger. One way to narrow the scope could be, for example, to focus the analysis on a single type of mission (e.g. peace-keeping operations in urban terrain), as opposed to addressing the whole range of possible missions. Or, the study could focus on all personnel aspects related to a particular operational task (such as civil-military operations, for example), or else cover a single aspect (e.g. types of skills required) across the whole set of operational tasks.

4.3 Movement and Manoeuvre

The challenges related to movement and manoeuvre in an urban setting are numerous and could be classified in several ways. The classification proposed here will serve to give the reader a general idea of the difficulties that are likely to be encountered. The proposed classification, consisting of two levels, includes specific challenges which could be tackled eventually through a collaborative effort by an international team:

1. **What to do (or “The Science of Movement and Manoeuvre”).** At this level, the theory behind movement and manoeuvre should be reviewed, to make the transition from the classical theory that is applicable to open spaces (and is based on linear concepts such as axes of advance, limits of exploitation and lines of departures) [37] to a theory that is applicable to urban terrain. The context of urban terrain has several features that need to be taken into account when developing new such theories which, once developed should make their way into the training process of the soldiers. Among these features are shorter lines of sight (because of the buildings), the multitude of potential hiding places for the enemy, which transforms the classical battlespace into a multitude of smaller battlespaces, which in turns brings the requirement of splitting the blue forces into a multitude of small semi-autonomous teams that need to tackle these smaller battlespaces separately, but in a coordinated manner [37]. Under such conditions, non-linear infiltration tactics are essential [37]. The freedom of movement can be significantly hampered by the presence of non-combatants, refugee movement, or even the physical configuration of roads (narrow roads, for example). The presence of buildings and the difficulty to clear buildings of potential threats (snipers, for example) will also make this movement slow.

2. **How to do it (or How to Implement the “Science of Movement and Manoeuvre” in Practice).** Another set of challenges related to the implementation aspects of the “science of movement and manoeuvre”, which in fact touches to a number of other domains. For example, one of the key factors that would enable successful movements and manoeuvres is situational awareness. In turn, the situational awareness depends on several factors such as the quality of the communications, the quality of data collected through the various sensors and how this data is transformed into useful information, the intelligence collection, or the C2 structures, to name just a few. All these domains present their own specific challenges in an urban context, which have already been discussed in this paper. However, a link between these domains and movement and manoeuvre is definitely worth making, to study the specific challenges and potential solutions, as they relate to supporting movement and manoeuvre operations. For example, the requirement of operating in small teams may place different demands on the C2 structure, demands which may not be satisfied by the traditional structures. Similarly, a link between movement and manoeuvre and fires should be made, specifically in the context of urban operations since a key role of movement and manoeuvre is to support the conduct of fires. The specific features of fires in urban terrain¹² will likely bring up specific features of movement and manoeuvre. For example, heavy utilization of ammunition, which is one of the characteristics of urban operations, will clearly have an impact on movement and manoeuvre (i.e., the requirement to carry more ammunition or to organize more frequent deliveries of ammunition to the soldiers). Other logistics aspects related to movement and manoeuvre in urban terrain would also be worth studying. In addition, looking for technological solutions to problems that are specific to movement and manoeuvre in urban operations could be another research avenue to explore. Some examples are provided in [38] and include combat identification, practical means to improve mobility within and outside buildings, remotely delivered wall- and door-breaching devices, climbing aids, air mobility and hands-free slings for all weapons.

The points discussed above represent a sample of a larger set of research activities in the area of movement and manoeuvre in the context of urban operations.

¹² The fires (direct or indirect) conducted in complex urban areas have their own specific features, due to the special characteristics of such areas (presence of buildings, non-combatants, etc.). For example, it is likely that only a limited selection of weapons can be used in urban operations, due to the requirement to minimize collateral damage, and also other constraints. In addition, it is also likely that the usage that will be given to some of these weapons in urban areas will be different from the usage that would normally be given to them on a different terrain.

4.4 Asymmetric Force Protection

In the recent decades and particularly in urban areas, the asymmetric threats and the use of unconventional means has changed the vision of military planners and has posed particular challenges to the defence staff, especially with regards to FP. In fact, in urban areas, the danger to military personnel comes mostly from the asymmetric and unconventional attacks, which consists of tactics employed by terrorist groups to carry out attacks while trying to avoid direct confrontation [39].

These asymmetric attacks are more noticeable in an urban environment since such environment facilitates operations by guerrillas, insurgents and other non-state groups and achieving their objectives. The asymmetric threats can move more freely and effectively in crowded urban areas since the detection and identification of hostile elements among a densely non-combatant population are extremely difficult. In addition, the effects of terrorist acts in urban areas are more important. Such attacks usually generate casualties, attract media attention and consequently have a great impact on public opinion. In these circumstances, FP is more challenging in urban environments than in any other type of terrain. The physical terrain may break up friendly forces and may restrict movement such that protection becomes difficult. The large number of non-combatants inhibits protective fires and adds to the complexity of the task of protection against asymmetric attacks. Moreover, in urban areas, the military and local infrastructure, the communication facilities, as well as the civilian buildings are more difficult to secure and protect. Past international operations have had to cope with asymmetric tactics, Improvised Explosive Devices (IEDs), ambushes, suicide bombings and hostage taking. The question of how to protect deployed personnel in urban areas has become central to the military. It then becomes important to undertake research in the field of FP, and especially against asymmetric attacks.

The literature review carried out for this study shows that FP issues against asymmetric threats have not been addressed to the extent required. Examples of subjects that could be tackled within this domain include the following: provide guidelines leading to an antiterrorist FP plan that balances FP requirements with specific mission needs and objectives; provide recommendations to improve the protection of personnel, information and critical resources in an antiterrorist context; identify the equipment needs (such as deployable equipment for the removal of explosive devices, or intrusion alarm systems for perimeter security) that will improve the perimeter security capabilities; identify the type of training that is required for antiterrorism FP and adapt personnel security courses to conditions of the operational theatre; identify how to better

achieve FP by developing PSYOPs, public affairs and CMO capabilities; identify how to improve intelligence for asymmetric threats and how to counter bomb attacks and IEDs, etc. The scope of such a study could be adjusted, depending on the time available. For example, the focus of the analysis could be placed on a single type of asymmetric attack, aiming to identify FP means, capabilities and training needed to counter that particular type of asymmetric attack. Or, international efforts could focus on proposing a new capability, aiming to identify its utility and the asymmetric attacks that it could counter.

4.5 Special Operations

The complexity of the urban environment and the need to counter terrorist attacks in such an environment change the way missions are conducted and give a crucial role to special operations. These operations are conducted by specialized military units and consist of a variety of missions, generally clandestine. Examples of such missions include the protection of people and facilities from terrorist attacks in urban areas; hostage rescue; attack of terrorist infrastructure; direct actions such as raids, ambushes, direct assault; special reconnaissance; urban counterinsurgency operations; unconventional warfare, civil affairs; psychological operations; actions taken to seize, destroy or recover WMD; information operations.

Based on the literature review carried out for this study, it appears that special operations have not been addressed. Comprehensive aspects need to be studied: the communications links between the intelligence capabilities needed to identify targets and SOF, and provide recommendations to how SOF can get high-quality intelligence on a real time basis in urban areas; the operational benefits and risks of having SOF working within local population; the education and specialized training needed by the SOF to achieve operational proficiency in multi-national urban operations; study the legal constraints (laws and rules of engagements) that might affect the conduct of multinational special operations missions; identify the logistic requirements for an urban theatre and the type of medical support needed for SOF; and finally assess how to coordinate psychological operations, information operations and civil affairs to help SOF reach their objectives.

4.6 Interaction with Non-Governmental Organizations

According to [40], the involvement of Non-Governmental Organizations (NGOs) in humanitarian and peace support operations is increasing. During the Kurdish crisis in 1991, 28 NGOs were involved in providing humanitarian aid,

but this number grew in Somalia to 78, in Rwanda to 170, while in Haiti and Bosnia, over 400 such organizations were active. This suggests the need for a significant coordination of efforts in order to achieve the desired end goals of both the military and the NGOs. The interaction between the armed forces and the NGOs is not limited to an urban context but the challenge is greater there due to the greater number of non-combatants and NGOs co-existing.

While in theory, “coordination of efforts”, “mutual support” and “collaboration” between the military and the NGOs, appear straightforward and evident, in practice there are several difficulties that are being encountered when implementing these concepts, and for which solutions are still being sought. Concepts of implementation problems could benefit from being addressed by a multi-national research group that might have access to a variety of past experiences and lessons learned. Examples of such difficulties are provided, in no particular order:

1. The co-presence of numerous NGOs and military organizations create an important challenge with multiple facets:
 - they all compete for a limited number of resources (such as roads, medical facilities, housing, radio communication frequencies);
 - it is difficult to remain constantly aware of actions, roles and responsibilities; in the resulting confusion, some aspects may remain unaddressed;
 - it is difficult to produce and agree on a coordinated planning effort;
 - there is an additional strain on the military to protect the NGO workers whom are not in a position to protect themselves;
 - communication, an essential element in all operations, is difficult to achieve in a satisfactory manner;
2. The NGO and military communities usually have different and sometimes conflicting objectives and views on the best ways to reach them.
3. Usually, military forces have a focused mission, roles and responsibilities and often a limited timeframe to complete their mission. They tend to have short-term operational goals, while the NGOs usually have long-term ones. In the process of reaching their short-term goals, the military may actually hamper some of the activities conducted by NGOs;
4. There can be lack of understanding of the roles and capabilities of the NGO and the military communities. There are situations in which a commander in the field does not know how to deal with all the NGOs involved, or even which NGOs are involved;

5. While the military forces have a clear, homogenous structure and clear operating rules, including a chain of command, the NGO community is definitely more heterogeneous. NGOs organizational levels range from well organized and autonomous to those with ad-hoc structures and dependent on others (military included) for their operations. In many of these organizations there is no chain of command and often no equivalent to a military commander;
6. Communication is a two-fold problem. In some situations, there may be a will *not* to share information, be it on the military side or on the NGO's side. On the other hand, even if the will to share information exists, the physical means to distribute this information may not be available. Generally speaking, the military forces have a high-tech approach to communications compared to some of the NGOs.

As presented in the previous sections, the list of problems identified here is not an exhaustive one. It was provided as a starting point to foster further discussions among the scientific community on the issues related to the interaction between NGOs and military forces in an urban context.

5. Conclusion

This document presented a literature review covering the most recent research activities of the last five years that have taken place within international research organizations such as NATO RTO, TTCP and ABCA, in the field of urban operations. The aim was to identify potential areas that have not been addressed yet by these organizations and which might benefit from a concerted international effort. Initially, three topics (1 to 3) were selected by the authors as prime candidates. Upon lecture of a preliminary version of this report, members of the TTCP JSA Group suggested an additional three topics (4 to 6) which were then elaborated upon by the authors. The six topics are summarized as follows.

1. **Logistics Support:** The context of urban operations creates many challenges in terms of logistics support, mainly because of the complexity of the physical terrain and the presence of large numbers of non-combatants. For example, the distribution process is more complicated as the supplies (ammunition, food, water, etc.) need to be delivered across the complex infrastructure, for example on several floors of a building, and sometimes manhandled up the stairwells. Also, the presence of non-combatants creates an additional burden for medical or supply services. Thus, it is recommended to address the problem comprehensively, from a clear definition of the logistics requirements in urban operations, to solutions to respond to those requirements.
2. **Human Factors Issues:** The human dimension is one of the most important issues in urban operations. However, relatively little effort has been spent on addressing human issues when compared to materiel issues. Areas that could be addressed in the vast domain of human factors include the following: identify the skills and training needed to ensure that soldiers are fully prepared to operate in an urban terrain, analyze interoperability issues from a personnel point of view, analyze organizational issues and current or proposed rules of engagement and analyze the human performance issues in urban military operations.
3. **Movement and Manoeuvre:** The freedom of movement and the ability to manoeuvre can be significantly hampered by the presence of non-combatants, refugee movement, or by the transportation infrastructure. Other characteristics of an urban terrain, such as short lines of sight and a multitude of potential hiding places for the adverse forces add to the level of complexity, making traditional

theories of movement and manoeuvre for open battlespaces, obsolete in an urban context. This context is characterized by a multitude of smaller battlespaces that need to be tackled separately and in a coordinated manner. The subject of transition from the classical theory of movement and manoeuvre in open spaces (based on linear concepts) to one that is applicable to urban terrain (where non-linear infiltration tactics are required), as well as the related implementation issues are two important questions that could benefit from the attention of the scientific community.

4. **Asymmetric Force Protection:** Asymmetric tactics, ambushes, suicide bombings and hostage taking are becoming more and more common in today's international operations and the question of how to protect deployed personnel from these threats is accordingly gaining more and more importance. Some of the topics that could be addressed in this field include the development of intelligence capabilities against asymmetric threats, the equipment required to improve perimeter security, the training of personnel to better respond to the terrorist threats and better force protection through psychological operations, public affairs and civil-military operations.
5. **Special Operations:** The complexity of the urban environment and the need to counter terrorist attacks in such an environment position special operations in a crucial role. Among the issues that could be tackled in this area include: the study of the communication links between intelligence capabilities and Special Operations Forces (SOF), the identification of the type of skills and training required by members of SOF, the assessment of operational benefits and risks related to the deployment of SOF among the local population and the legal constraints that might affect such operations, especially in a multi-national urban context.
6. **Interaction with Non-Governmental Organizations (NGO):** In an urban environment, due to the presence of non-combatants, NGOs are bound to exist and probably in large numbers. As part of the interaction between the NGOs and the armed forces, concepts such as "coordination of efforts", "mutual support" and "collaboration" are important, but also difficult to implement. As such, research could be carried out on the implementation of these concepts. Potential research directions include: communication issues with a large number of organizations, alleviate the consequences of having different missions, roles and responsibilities

by the military and the NGOs, different timeframes and different approaches.

The reader should note that the results presented in this paper provide a snapshot of some of the key issues. They are mainly provided as a starting point to foster further discussions among the scientific community on the present and future urban operations.

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List of symbols/abbreviations/acronyms/initialisms

ABCA	America, Britain, Canada and Australia
C2	Command & Control
C4	Command, Control, Communications, Computers
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
C4ISTAR	Command, Control, Communications, Computers, Intelligence, Surveillance, Target Acquisition and Reconnaissance
CAPS	Capabilities Assessment Seminar
CIR	Critical Information Requirements
CM	Consequence Management
CMO	Civil-Military Operations
DOTMLPF	Doctrine, Organisation, Training, Material, Leadership, Personnel and Facilities
FP	Force Protection
HFM	Human Factors & Medicine
HUM	Human Resources and Performance Group
HUMINT	Human Intelligence
IED	Improvised Explosive Devices
IR	Information Requirements
IST	Information Systems Technology
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
IT	Information Technology
JIACG	Joint Interagency Coordinating Group
JSA	Joint Systems and Analysis Group
JUW	Joint Urban Warrior
JUW04	Joint Urban Warrior 2004

JUW05	Joint Urban Warrior 2005
LoAC	Low of Armed Conflict
M&S	Modeling & Simulation
MNE	Multi-National Exercise
MoEs	Measures of Effectiveness
MoOE	Measures of Operational Effectiveness
MOOTW	Military Operations Other Than War
MoPs	Measures of Performance
MoRs	Measures of Response
MoSE	Measures of System Effectiveness
NATO-RTO	North Atlantic Treaty Organisation – Research and Technology Organisation
NGO	Non-Governmental Organisations
NLW	Non-Lethal Weapons
OIF	Operation Iraqi Freedom
PR	Personnel Recovery
PSYOP	Psychological Operations
QAP	Quadripartite Advisory Publications
RF	Radio Frequency
SAS	Systems Analysis & Studies
SEN	Sensors Group
SET	Sensors & Electronics Technology
SOF	Special Operations Forces
TRL	Technology Readiness Level
TTCP	The Technical Cooperation Program
USECT	Understand, Shape, Engage, Consolidate, Transition
USJFCOM	US Marine Corps and US Joint Forces Command
USW	Urban Seminar Wargame
WMD	Weapons of Mass Destruction
WPN	Conventional Weapons Technology Group

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This document presents a literature review covering the most recent (i.e., last five years) activities that occurred in the field of urban operations within international research organizations such as NATO Research and Technology Organization (RTO), The Technical Cooperation Program (TTCP) and the organization supporting the armies of United States, United Kingdom, Canada and Australia and known as ABCA (America, Britain, Canada and Australia). It aims to identify potential areas of interest that have not been addressed yet by these organizations and which might benefit from a concerted international effort. Six such areas have been identified: Logistic Support, Human Factors, Movement and Manoeuvre, Asymmetric Force Protection, Special Operations, and Interaction with Non-Governmental Organizations.

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