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Situation Analysis for the Tactical Army Commander (SATAC)

Scoping study report

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Defence R&D Canada – Valcartier
Technical Memorandum
DRDC Valcartier TM 2006-408
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This document results from S&T work conducted under DRDC project 12of (Situation Analysis for the Tactical Army Commander).

Abstract

We present the project SATAC (Situation Analysis for the Tactical Army Commander). The goal of this project is to give the Canadian Army the means to build an automated reasoning capability in order to support Situation Analysis, a process by which the human gains Situation Awareness (SA). We explain our general approach to address these problems we have identified to be of interest to our client, the Directorate of Land Requirements (DLR).

Résumé

Ce texte présente le projet ASCAT (Analyse de la Situation pour le Commandant d'Armée Tactique). Le but de ce projet est de donner à l'armée de terre canadienne les moyens de se construire une capacité de raisonnement automatisé pour supporter l'analyse de la situation, un processus par lequel l'humain acquiert une conscience de la situation. Nous allons présenter notre approche pour attaquer les problèmes d'intérêt que nous avons identifiés du point de vue de notre client, la Direction - Besoins en ressources terrestres.

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Executive summary

Situation Analysis for the Tactical Army Commander (SATAC)

Éric Dorion, LCol. Michel Gareau, Jean Roy; DRDC Valcartier TM 2006-408; Defence R&D Canada – Valcartier; September 2008.

Situation Analysis for the Tactical Army Commander (SATAC) is an Applied Research Project (ARP) evolving under the auspices of the DRDC 12o - Command thrust. Its military client is the Directorate of Land Requirements (DLR). The project officially started in May 2005 and will end in April 2009. The first year was devoted to the conduct of a scoping study that enabled the definition of the key activities that will be undertaken in this project. This report aims at explaining these activities.

The name of the project spells out its broad concern and its targeted client, respectively Situation Analysis (SA) and the Tactical Army Commander (TAC). Informally, SA is the process by which one gains Situation Awareness, which in turn is a mental model of the state of the environment of interest. The TAC can be any soldier or group leader that has been assigned tasks and resources in order to accomplish a tactical objective in a specific environment.

The goal of SATAC is to give the Canadian Army the means to build an automated reasoning capability in order to support SA. In order to achieve this, SATAC will pursue three primary objectives. First, SATAC will make an ontological commitment towards the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM) because it is currently the most comprehensive military coalition operations ontology and an integral part of the current Army's IT spectrum. Second, SATAC will study the state-of-the-art knowledge representation and inference engine mechanisms in order to develop an automated reasoning capability. Third, SATAC will conduct cognitive engineering activities with the TAC, placed in a Full-Spectrum Operations scenario in order to bring SATAC under a perspective of strong operational relevance. The realization of these objectives will ultimately lead to the development of a knowledge-based SA Support System (SASS).

The expected benefit of a knowledge-based SASS is to relieve the burden of the TAC by handling some aspects of the creation of new from existing information through the use of mathematical logic. This is a capability that the Army currently lacks and impedes on its efficiency.

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Situation Analysis for the Tactical Army Commander (SATAC)

Éric Dorion, LCol. Michel Gareau, Jean Roy ; DRDC Valcartier TM 2006-408 ;
R & D pour la défense Canada – Valcartier ; septembre 2008.

ASCAT (Analyse de la Situation pour le Commandant d'Armée de terre Tactique) est un projet de recherche appliqué (PRA) évoluant sous l'égide du vecteur 12o, du domaine de recherche "commandement". Son client militaire est la Direction - Besoins en ressources terrestres. Le projet a officiellement débuté en mars 2005 et se terminera en avril 2009. La première année du projet a été consacrée à une étude des activités clés qui seront entreprises dans le cadre de ce projet. Ce rapport vise à décrire ces activités.

Le nom même du projet énonce son sujet global et son client visé, respectivement l'analyse de la situation (AS) et le commandant d'armée de terre tactique (CAT). De façon informelle, l'analyse de la situation est le processus par lequel quelqu'un acquiert la "conscience de la situation", qui à son tour est un modèle mental de l'état de l'environnement d'intérêt. Le CAT peut être tout soldat ou tout chef de groupe qui s'est vu assigné des tâches et ressources afin d'accomplir un objectif tactique dans un environnement déterminé.

Le but du projet ASCAT est de donner à l'armée de terre canadienne les moyens de se construire une capacité de raisonnement automatisé pour supporter l'analyse de la situation. Pour atteindre son but, ASCAT poursuivra trois objectifs primaires : Premièrement, ASCAT prendra un engagement ontologique envers le modèle de données "Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM)", parce que c'est présentement l'ontologie des opérations militaires en coalition la plus complète et qu'elle fait partie intégrante du spectre des technologies de l'information de l'armée de terre. Deuxièmement, ASCAT étudiera les mécanismes de représentation de la connaissance et d'engins d'inférences les plus récents afin de permettre le développement d'une capacité de raisonnement automatisé. Troisièmement, ASCAT entreprendra des activités d'ingénierie cognitive dont le CAT, placé dans un scénario d'opérations à large spectre, sera l'objet ; ceci afin de bien situer ASCAT dans une perspective de pertinence opérationnelle. La réalisation de ces objectifs mènera ultimement au développement d'un système d'aide à l'analyse de la situation basé sur la connaissance.

Le bénéfice attendu d'un système d'aide à l'analyse de la situation basé sur la connaissance est de soulager le fardeau du CAT en prenant en charge certains aspects de la création de nouvelle information à partir de celle existante en utilisant la logique mathématique. Ceci constitue présentement une capacité que ne possède pas l'armée de terre et qui freine son efficacité.

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1 Introduction

Nowadays, information has become part of the arsenal of the militaries. In fact, information is a key element around which the world as we know it revolves. It is well recognized that controlling information in its acquisition, processing and dissemination often determines dominance on the terrain. In this sense, information technologies (IT) play an important role by supporting certain areas where the human alone would not make the cut.

Of the areas addressed by IT are those that support the gathering of information, its organization into specific structures, its proper usage to support the human decision process and its shipping to other information processing nodes. These specific areas do not happen to have been chosen by chance. On the contrary, they follow closely the human way of processing information depicted by the well-known Observe-Orient-Decide-Act (OODA) loop [1]. The reason for this is that the human mind is the most capable processing apparatus that we know so far, and we try to mimic its functions. IT will typically target one or more aspect of the OODA loop, rarely in its entirety due to the sheer complexity each aspect can hide.

The "orient" phase of the OODA loop has to do with how "raw" information is organized and processed so that the human (subject to the OODA process) gains a perception of the situation that reflects the reality. This phase determines the acuteness of the decisions that will be made by the human given a certain situation. Several cognitive processes are involved in the orient phase, one of which contributes to the rationalization, reduction and creation of derived information. This process is known as "fusion". For example, let's consider three information elements:

1. Mr. Dorion works at DRDC-Valcartier since 1995,
2. Defense R&D Canada - Éric Dorion (a simple name tag we wear at conferences)
3. Isenor, A., Dorion, É., The Use of GCCS in the Canadian Navy and its Relationship to C2IEDM, TM 2004-197, DRDC - Atlantic, December 2004, 46 pages.

Given these statements, the reader naturally has the tendency to infer that "Mr. Dorion", "Eric Dorion" and "Dorion, É" are in fact the same person. One could say that a simple mechanical pattern matching would do the trick, but the human is able to ascertain the degree of confidence of this matching by considering unstated facts like the context of assertion (You knew that the writer deliberately wanted to lead you to that conclusion). The machine can only ascertain its conclusion from the string subsets that match, and relate the three statements through structure. The human embraces a far richer set of rules to correlate them. Why is it that the humans are so natural (good or bad) in doing this? Can we extract this human faculty, at least in part, and integrate it into machines so to lessen the cognitive burden on humans? What should we do or not do in this sense? These are some of the fundamental questions we would like to tackle within the SATAC project. This work was done under the SATAC project (12of) between November 2005 and June 2006.

2 SATAC Project Background

Along with the general research question mentioned in the introduction, this section tries to situate the project with certain aspects. Firstly we consider SATAC with respect to DRDC Thrust 12o - Command's vision. Then, we state the primary objectives, the expected benefits and outcomes and the key measures of merit. Finally, we explain SATAC's positioning in terms of scoping study and long-term vision.

2.1 DRDC Thrust 12o – Command

SATAC's funding comes from DRDC Thrust 12o - Command. The thrust objectives are:

> *To meet the army's need for S&T necessary to establish shared intent among commanders and their teams in a highly networked land force, and for the development of technology, doctrine, training and education approaches that can support this establishment of shared intent.*

Among other things, Thrust 12o supports and funds projects that focus on Command as a human capability that can be assisted by technology. In this context, Command is given two working definitions. The first one derived from doctrine defines Command as

> *the creative expression of the human will necessary to accomplish a mission through the exercise of the authority vested by the national government and the chain of command for the direction, coordination and control of military forces.*

The second one was established from the broader scientific community as

> *the creative and purposeful exercise of legitimate authority to accomplish the mission legally, professionally and ethically.*

The Thrust recognizes that Command is very broad as a concept and mitigates this by focusing its study around the theme of "Distributed Command and Control", until 2010. This push of Distributed C2 comes in recognition of the fact that the Army Command structure is highly distributed as opposed to the more centralized Command structures of the other services (Navy and Air). Secondly, the advent of IT along with better communications capabilities have opened the possibility of shifting the actual function of Command from where it happened traditionally to other areas of the operational terrain. These two aspects of modern Command generate several fundamental questions and justify research and development.

For commodity, Thrust 12o maps the R&D projects it supports to three general categories: 1) Human Command, 2) Command Support, and 3) Communications and Information Systems. Their brief description below comes directly from their website [2].

2.1.1 Human Command

This category includes all human centered research - i.e., involving psychology, social psychology, anthropology, etc. Examples include: intellectual and emotional flexibility and adaptability; analytical vs. intuitive decision making, psychological resiliency, leadership, team cohesion, fatigue, stress, etc. In essence this category includes research that elucidates how humans command, and how to improve human command capability through selection, training, professional development, etc.

2.1.2 Command Support

This category describes research intended to support human command capability, specifically by providing external support structures and processes. Examples include: expert systems, human factors engineering, human-machine interfaces, organizational structures, training strategies, learning curricula, computer-support cooperative tools, battlespace visualization, etc. This category involves research that must, sooner or later, either involve human testing or at least in-depth knowledge of human behaviour.

2.1.3 Communication and Information Systems

This category encompasses research that is of a purely technological nature - i.e., though ultimately intended to support human command capability, it requires no particular knowledge of human behaviour or human science. Examples include: bandwidth issues, encryptions technologies, node splicing, network synchrony, etc.

SATAC actually spans these 3 categories, with a strong emphasis on Command Support. Since SATAC's general research question is to address Situation Analysis, which is essentially a cognitive process to begin with, and to derive supporting technologies, one will understand that the project will effectively cover Human Command, Command Support and Communications and Information Systems aspects.

2.2 Primary Objectives

From the beginning, the broad objective of SATAC has been to apply and exploit state-of-the-art science and technologies that pertain to the Situational Analysis and Information

Fusion (SAIF) domain in order to support who we will define later as the Tactical Army Commander. In order to do so, there is a need to conduct as many activities as necessary to define the different parts of a system that supports the human cognitive ability to gain awareness. We call this system a Situation Analysis Support System (SASS) and we will briefly define its components in section 1.9. One can understand that such a system can be studied from multiple angles, so many in fact that SATAC will not be able to cover. The scoping study aimed at identifying some of the crucial parts that should be addressed in order to build such systems and this will be discussed in section 1.9 also.

So what is the achievable goal of SATAC? To answer this question, we must consider many aspects:

- The concerns of our client, DLR-4,
- The concerns of our DRDC sponsor (Thrust 12o),
- The current Army IT spectrum
- The Army contribution, not only in terms of funding but especially in terms of Subject Matter Experts (SMEs) availability,
- The number of DRDC scientists that can be deployed to SATAC,
- The type of expertise of the DRDC scientists,
- The contribution from Defense Industry,
- And so on...

The key aspect is to consider that the project is limited in terms of budget, in terms of human expertise and in time. Therefore we must focus on project objectives that are achievable within these limits. After a year of scoping the project, we have established, in all considerations and fairness, some objectives that we, as scientists, would like to achieve by the end of the project.

The primary objective of SATAC is to give the Canadian Army the means to build an automated reasoning capability in order to support Situation Analysis, a process by which the human gains Situation Awareness.

There are of course some boundaries and assumptions that must be stated in order to clarify our position. The following arguments are just but a few.

2.2.1 JC3IEDM Conformance

As of today, there is no formal or recognized JC3IEDM conformance test. However, the Army abides by this NATO standard to set its ontological context in order to ensure systems-to-systems interoperability, and has devoted a significant part of its resources to incorporate it as a component of its architecture. Since there is a need for SATAC to manipulate structured information, the choice of JC3IEDM comes naturally. However, in order to mitigate the risk associated with different projects' delivery schedules that could impair our ability to deliver, we will work on the Multilateral Interoperability Programme (MIP) specification of the JC3IEDM instead of its Canadian implementation and associated components. We realize that this imposes a certain overhead to adapt our proposed technologies, but this approach has worked very well in the past, given our expertise of the JC3IEDM and Army guidance. This approach also brings us closer to our international fellow colleagues that already use the MIP specification and thus gives us more flexibility.

2.2.2 Automated Reasoning

Automated Reasoning is a sub-branch of Artificial Intelligence (AI) and also closely related to AI technologies such as expert systems. We know about a certain perception that an automated reasoning capability suggests that the human is "brought out-of-loop". It is NOT so. Situation awareness is a cognitive state and therefore is not something that can live outside in an AI system. An automated reasoning capability really comes in support of the mental process, situation analysis, leading to situation awareness, by suggesting some inferences that can be mathematically derived. This capability aims at relieving the human over-burdened by unnecessary calculations that could impair his capacity to gain awareness.

2.2.3 Operational Relevance of a SASS

SATAC will devote significant efforts to understand the operational context under which tactical army commanders (TACs) are deployed nowadays, mainly through the conduct of cognitive engineering studies. However, one must understand that in this sense, the Canadian Army (and any other Army forces in the world for that matter) finds itself in a constant learning process when it comes to modern operations. Doctrine is scarce if not non-existent and access to TACs is very difficult to obtain, simply because a lot of them are actually deployed.

On another note, AI research has hit a big wall a few years ago when it was realized that the depth of reasoning is usually inversely proportional to the breadth of knowledge it addresses. For example, typical AI applications will focus on relatively narrow subjects and go deeper in terms of knowledge manipulation (e.g. A medical diagnosis and treatment knowledge base). The human mind is no stranger to such consideration. A SME is usually associated to a certain field of expertise. When placed in another context of expertise, his judgment is as good as the average person.

Knowing this, one can ask about the value of a SASS in an ever-changing operational context. It is very difficult for us to answer this question at this point. We can only state for now that we are aware of this fact and that we will try to find a balance in breadth vs depth of knowledge for this type of application. We may also come to the conclusion that this type of application is not applicable to this context and it will be our duty to fully explain the conditions under which we inferred this.

2.3 Expected Benefits and Outcomes

One of the obvious benefits of having a SASS for the tactical commander is to rely a bit more on technology to relieve the burden of information processing. As the Army is currently building a command and control information system (C2IS) suite that aims at bringing sensor information ("sensor" including the human) to the commander, one can easily extrapolate the problem of overload that ensues. Therefore, technologies that aim at "rationalizing" information (e.g. information fusion technologies) are necessary.

Notwithstanding the fact that information fusion helps in "depolluting" the information available, it also supports the derivation of new information. In this sense, it embodies the AI concept of automated reasoning thus becoming a tactical decision aid to the commander. The derived information products can be of several kinds and one of SATAC's goals will be to determine some of them. As of today, we believe that this capability is not available to TACs.

As for SATAC, the Applied Research Project (ARP), it is hoped that the body of knowledge gained by the end of the project will be sufficient to support a more encompassing endeavour like a Technical Demonstration Program. While a TDP aims at producing technology suites that are closer to deployable systems, an ARP is more centered on the production of a knowledge corpus usable to the TDP. If SATAC is keen to build and use technology to demonstrate its concepts, one must understand that the efforts needed to align SATAC's technology with the actual (or foreseen) Army IT components do not belong to an ARP effort. This relative independence of the ARP enables the scientists to explore the more adventurous aspects of their field and when something is discovered, a more suitable delivery program like a TDP can be used. For this, we hope that SATAC will become a TDP.

2.4 Key Measures of Merit

SATAC adheres to the principles enunciated in [3] as to how measures of merit (MoMs) should be set up. In this regard, a high-level measure of merit must be identified. Conveniently enough, SATAC spells it out: Situation Analysis. That is, the scientific and technical merit of SATAC must be measured against its added capacity to improve the cognitive process of tactical army commanders to gain a state of situation awareness within a specific operational context. This MoM, abstract and qualitative by nature, is referred to in [3] as a Measure of Effectiveness (MoE). To assess it, we must create a hierarchy of Measures of Performance (MoPs) that are quantitative by nature and against which measures can be taken. Dorion in [4] also shows how and where in a system should be placed some "instruments" that actually measure the low-level MoPs and thus the high-level MoE. When considered early enough in the design process, this approach enables the creation of a closed-loop or feed-back system capable of correcting its behaviour in trying to optimize its MoPs. This is capital in SATAC as a comprehensive knowledge-based system should encompass a learning mechanism.

As of this writing, it is too early to create this hierarchy of MoMs (less the Situation Analysis high-level MoM). However, we stress out that its identification must take place in the very first design step and follow the same iterative building that the system should have.

2.5 SATAC Scoping Study

Considerable time was devoted in SATAC's scoping study year to assess the breadth of activities that should be conducted in order to leave us at the end with the necessary and sufficient knowledge to develop an implementable solution. We repeat that SATAC's goal is to give the Canadian Army the means to build an automated reasoning capability in order to support Situation Analysis. Of course, the project can be tackled from infinite different viewpoints, all of which can be very important. With limited financial resources and finite human resources, it must be scoped down to the key activities that are deemed to have the most beneficial impact for the project to be considered a success. In turn, these key activities must be those for which we truly have (or can acquire) competence and expertise. Section 3 describes in general terms the aspects that must be taken into account to build a SASS and the environment in which it would evolve. For any given amount of resources we can devote to the project, the number of activities conducted in the project will invariably affect the depth actually reached in each of these activities. We must seek a balance between breadth and depth. Considering the extreme positions can be useful in establishing a balance:

> *Breadth over depth* is this approach where a very large number of activities would be pursued at a rather superficial level. The problem with this approach is that it trivializes the fundamental challenges inherent to each activity. An example of this approach is to do conduct an integration of existing commercial software. While it is necessary, it is not sufficient as it brings nothing to our comprehension.
>
> *Depth over breadth* is this approach where a considerable amount of work would be devoted to very few selected activities. The problem with this ap-

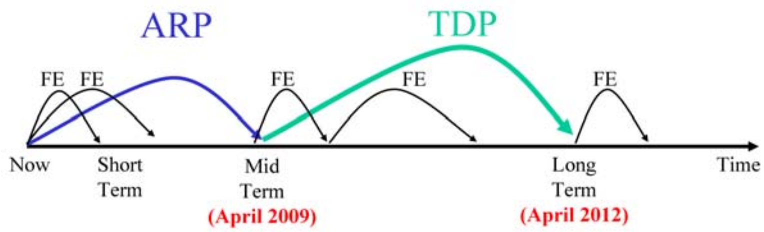

Figure 1: SATAC's Long-term Vision

proach is that the ensuing knowledge is hardly applicable to the immediate problem of the Army. For example, while the discovery of a new search algorithm would greatly impact the scientific community, it would take years to see it effectively impact the military systems.

In SATAC, we will try a hybrid approach where several activities will be pursued but with a special focus on a limited few. For instance, there will be activities in automated reasoning, knowledge representation, software engineering and experimentation design. However, we have no claim in discovering "disruptive" technologies in these specific domains. On the other hand, we want to dig deeper into automated reasoning, machine learning and knowledge representation because this is something that, we think, currently is lacking to the Army. In the end, this hybrid approach will yield a profound understanding of selected research domains into an implementable solution.

2.6 SATAC Long-term Vision and Program

SATAC's Applied Research Project is technically due in April 2009. It is hoped that its results will be significant enough that it will justify a Technical Demonstration Program (TDP). Typically, a TDP goes on for 3 to 5 years. Figure 1 shows a timeline of an on-going effort to bring the current state of knowledge to a working prototype.

While the very large part of activities supported by the ARP and TDP (blue and green curved line respectively) are those established and funded in the beginning of both efforts, we understand (and hope!) that some intermediary knowledge could readily be transitioned to the current army's systems. These punctual efforts are depicted by the short black curved arrows on Figure 1. Since these activities are unlikely to have been planned in the beginning of the ARP and the TDP, it assumed that the Army (or another client instance) would provide the necessary funds to support these extra activities.

SATAC's long-term vision aims at providing the ideal environment for the project's development. On one hand, keeping a relatively fixed set of activities will help in terms of project management and stability (scientists love stability) and on the other hand, providing a mechanism to quickly transition discoveries to fieldable solutions will help the client find useful aspects of the project that may be more relevant to him.

3 SATAC R&D Framework

Thus far we presented SATAC in general terms, stating the broad research question of information fusion, situation awareness and situation analysis. We also brought SATAC in light with its objectives, its expected benefits and outcomes, its measures of merit scheme and its projection into future research programs. This chapter digs a little bit more into SATAC's concerns in terms of its driving operational context, a more detailed view of situation awareness and analysis, a brief description of a knowledge-based Situation Analysis Support System (SASS) and a supporting framework for its development. Finally, SATAC's current R&D focus (targeted R&D depth of SATAC) will be explained. Some concepts herein are introductory and are either to be the focus of future deliverables or already documented [5, 6].

3.1 Driving Operational Context for SATAC

We mentioned in section 2.5 that SATAC needs to conduct a fair number of activities in order to contribute in a significant way to the Army's systems (existing or in development). One of the key aspects to support this is to situate the current state of affairs in terms of current operations. Indeed, one cannot develop a system without any idea of the environment in which it shall be deployed. This is particularly true for military systems. Also, the main actor interacting with the system must be known and his actions defined. We cannot stress out enough the importance of this step in the development process as it greatly influences the relevance of the final solution to the client.

3.1.1 The Tactical Commander

We define a tactical commander as any leader with an assigned mission and allocated resources who is operating in a complex and austere environment, characterized by high risk, often in high stress, with no supporting or analytical staff and limited time to react to events. To successfully meet his tactical objective, it is key that this tactical commander clearly understands the intent of his higher commanders. It is this crucial understanding that will allow him to select the best resources to accomplish the task at the proper place and time and quickly react to unforeseen events while always maintaining his focus on the overall mission objective. In the more classical maneuver warfare context, tactical commanders were typically brigade or company commanders. Nowadays, in the new operational environment, a tactical commander may be a platoon, section, a team or even a vehicle commander. Crucial tactical decisions are now taken at the farthest edge of the battlefield.

3.1.1.1 The Levels of War

Military activity has been categorized into three levels: strategic, operational and tactical. These levels of conflict help commanders to visualize a logical flow of operations, allocate resources, and assign tasks to subordinates. Each level is defined by the outcome intended; not by the level of command or the size of the unit or formation involved. While the levels form a hierarchy, there are no sharp boundaries between them and they often overlap.

At the top of this hierarchy is the strategic level of conflict. In the broadest sense, strategy involves the employment of a nation's resources (political, economic, moral, scientific, technological, informational, and military) to achieve the objectives determined to be in the national interest. Military strategy is a component of national strategy. It provides direction for the use of military power to achieve national objectives by the application of force or the threat of force.

At the operational level, a commander prescribes what military actions are necessary to achieve the strategic aim. He does this by articulating the military intent of the operation, by planning sequential military actions to achieve this intent, and by initiating and sustaining such actions. At this level, commanders design, prepare and conduct joint campaigns and major operations, each of which comprise a series of battles, engagements and other actions.

The operational level is not defined by the number and size of forces or the echelon of headquarters involved. In a large scale conflict, a corps may be the lowest level of operational command. However, in smaller scale conflict, operational level activity can take place at much lower levels. If a military force, of whatever size, is being used to achieve a strategic objective, then it is being employed at the operational level.

At the tactical level, battles, engagements, and other actions are planned and executed to accomplish military objectives established by the operational level commander. The tactical level should never be viewed in isolation, for tactical success alone does not guarantee strategic success. Battles and engagements generally shape the course of events at the operational level, but they become relevant only in the larger context of the campaign. The campaign, in turn, only gains meaning in the context of strategy. This is illustrated by the dramatic tactical victory at Cannae that nonetheless failed to bring Hannibal success in his campaign to conquer Rome; in the same way US operations in Vietnam achieved consistent tactical successes but they did not lead to strategic victory. A comprehensive view is required to understand that the three levels of conflict are inextricably linked.

This delineation into levels of conflict has limitations. Factors such as the advent of information technology are compressing these levels, blurring the distinction between each. The important lesson is not to discern at what level a certain activity takes place or where the transition occurs between levels, but to ensure that from top to bottom and bottom to top all activities are coordinated and focused towards achievement of the strategic objective. An understanding of the complexities of working at the operational level in a joint and combined context is essential for the Canadian army to execute, or even to cooperate in the planning and conduct of, campaigns and major operations. Commanders need to develop an appreciation of the interaction of the levels of conflict to provide timely and astute advice to the government on the advantages and disadvantages of the use of military force in domestic and international operations [7].

3.1.1.2 A Strategic Corporal

> "The inescapable lesson of Somalia and of other recent operations, whether humanitarian assistance, peace-keeping, or traditional warfighting, is that their outcome is more than likely to hinge on decisions made by small unit leaders, and by actions taken at the lowest level. In today's and tomorrow's deployment, success or failure will rest, increasingly, with the individual soldier and with his ability to make the right decision at the right time at the point of contact. Sub-tactical teams will undoubtedly have to accomplish their assigned tasks without the direct supervision of senior leadership. Those teams will be required to deal with a bewildering array of challenges and threats. In order to succeed under such demanding conditions they will require unwavering maturity, judgment, and strength of character. Most importantly, these missions will require them to confidently make well-reasoned and independent decisions under extreme stress – decisions that will likely be subject to the harsh scrutiny of both the media and the court of public opinion. Under those circumstances, our junior leaders will potentially influence not only the immediate tactical situation, but the operational and strategic levels as well. Their actions, therefore, will directly impact the outcome of the larger operation." [8]

3.1.1.3 Power to the Edge

During a recent presentation, Dr Margaret Myers, Principal Director, Chief Information Officer, Department of Defence said that "the real power to the edge comes from human ingenuity enabled by data and software application. Communication networks are essential but are valueless without the ability to ensure that data are reliable and that operators have the ability to use the data in an integrated manner... Horizontal Fusion represents the investment necessary to procure the means and tools to allow smart pull and data fusion; the sense making of data by users." Considering the very nature of today's complex operational environment and the somewhat highly technological (and quickly evolving) C4ISR assets available to our forces, operators and their tactical commanders are literally drowning in information overflow. The problem is not obtaining information anymore but rather discovering within a sea of often conflicting information the right information which can make "the difference" and to provide the capability to put it in context with other relevant knowledge in a specific situation. The application of such a principle in the current operational environment require that those tools be made available at the lowest possible level so that tactical commanders (at any level) can quickly understand their situation as it evolves and make the proper decision.

3.1.2 Asymmetric Threat

For more than 30 years, Canada structured and prepared itself to face the ominous Soviet "bear". In the last decade however, a more insidious threat has slowly emerged and Canada, much like most of its Western allies, now has to adapt and poise itself to react to sudden and seemingly unpredictable nature of "serpent-like" attacks of failing nations and terrorist organizations. Since 2002, Canada has been engaged with the United States and its coalition partners in counterinsurgencies operations in different part of the world and namely in Afghanistan. When considering operations in "Low Intensity Conflict" (LIC) which often involves Counter Insurgency Operations (COIN), the nature of the threat becomes much more elusive and "non-linear" thus the label of "Asymmetric threat".

> "The riveting reality of September 11 made clear the importance of understanding the asymmetric threat spectrum and how it places our support capabilities at risk. One important difference from the days of the Cold War is how an adversary might respond to our military actions. Today, that response is most likely asymmetric, in that while we would strike a military or terrorist target with modern precision weapons, the adversary may choose an entirely different response. As we saw on September 11, critical infrastructure facilities previously assumed to be safe havens could be at risk to kinetic threats. Support personnel who reside in those facilities could be at risk to chemical and biological threats, and there could be threats to the information–the very information networks that provide the technical basis for net-centric/enabled operations. All three of these elements of the asymmetric threat spectrum must seriously be considered, singly and in combination. The events of September 11th and its aftermath demonstrated with crystal clarity that asymmetric threats are the new reality" [9]

Here are examples of some forms the asymmetric threat spectrum could take:

- Kinetic Threat to personnel, organization or Critical Infrastructure Facilities,
- Covertly placed explosives,
- Projectile delivered explosives,
- Suicide attacks/bombings,
- Chemical/Biological Threats to Personnel,

- Aerosol delivered persistent chemical/biological agents,
- Insider delivered biological agent,
- Information Threat to Networks/Computing Systems,
- Disclosure of operations/business details,
- Deception causing loss of confidence in a system,
- Denial of system resources to support operations/business,
- Usurpation of system resources for criminal purposes.

3.1.3 Three-Block War and Full-Spectrum Operations

"The rapid diffusion of technology, the growth of a multitude of transnational factors, and the consequences of increasing globalization and economic interdependence, have coalesced to create national security challenges remarkable for their complexity. By 2020, eighty-five percent of the world's inhabitants will be crowded into coastal cities – cities generally lacking the infrastructure required to support their burgeoning populations. Under these conditions, long simmering ethnic, nationalist, and economic tensions will explode and increase the potential of crises requiring military intervention. Compounding the challenges posed by this growing global instability will be the emergence of an increasingly complex and lethal battlefield. The widespread availability of sophisticated weapons and equipment will "level the playing field" and negate our traditional technological superiority. The lines separating the levels of war, and distinguishing combatant from "non-combatant," will blur, and adversaries, confounded by "conventional" tactics, will resort to asymmetrical means to redress the imbalance. Further complicating the situation will be the ubiquitous media whose presence will mean that all future conflicts will be acted out before an international audience.

Modern crisis responses are exceedingly complex endeavors. In Bosnia, Haiti, and Somalia the unique challenges of military operations other-than-war (MOOTW) were combined with the disparate challenges of mid-intensity conflict. The US Marine Corps has described such amorphous conflicts as – the three block war – contingencies in which soldiers may be confronted by the entire spectrum of tactical challenges in the span of a few hours and within the space of three contiguous city blocks. The tragic experience of U.S. forces in Somalia during Operation Restore Hope illustrates well the volatile nature of these contemporary operations." [8]

3.1.4 Effects-Based Operations

In *The Art of War*, Sun Tzu wrote: "Those skilled in war subdue the enemy's army without battle. They capture his cities without assaulting them and overthrow his state without protracted operations."

Effects-Based Operations (EBO) is an approach to the tactical employment of resources that steps away from the typical objective-oriented methods of yesterday's maneuver warfare. Instead of just applying forces in order to capture or seize an objective, EBO offers alternatives in the employment of resources and manoeuvre elements in such a way to not only meet the higher commander's intent, but also potentially reduce fatalities, collateral damage, and cause unforeseen chaos in an otherwise already complex situation. More importantly, it allows deliberately planning, anticipating and understanding what impacts will this resources employment have on the surrounding environment. EBO requires the use of creative, critical thought processes and deliberate methodologies for planning, executing, and assessing operations that are designed to create the specific effects necessary to achieve their intended objectives. In Canada, the current planning methodology used by staff officers is known as the Operational Planning Process (OPP). EBO is a deliberate effort to fully exploit all capabilities and resources available to a commander. Therefore, all possibilities of creating an effect on the battlefield - or its environment - albeit lethal, non-lethal, kinetic or non-kinetic can and should be considered. EBO becomes even more relevant in today's context as it applies directly to the full spectrum of operations (FSO) from humanitarian relief to major combat operations, including COIN and stability and support operations (SASO). EBO provides military planners with a methodology to maximize the use of virtually all of the resources available to them. It opens possibilities to adopt options which can greatly reduce fatalities (on both sides) and apply force at the right place and time to achieve specific effects.

EBO is applicable at all levels of decision-making; strategic, operational and tactical. However, as you get deeper within the tactical - and even sub-tactical realm - the use of structured and linear methodology such as the OPP does not offer sufficient flexibility to allow commanders to adapt, react and make decision quickly enough. In an attempt to step away from using the OPP at the tactical level, the British Army adopted a more intuitive and flexible methodology based on a revised combat estimate process. The "Seven Questions/Combat Estimate" was therefore introduced in 2001 to simplify and speed up the planning process at Battle Group (BG) level and below. The seven questions are:

- What is the enemy doing and why?
- What have I been told to do and why?
- What effects do I want to have on the enemy and what direction must I give to develop my plan?

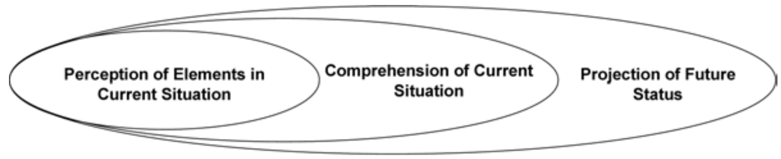

Figure 2: Endsley's Situation Awareness

- Where can I best accomplish each action/effect?
- What resources do I need to accomplish each action/effect?
- When and where do the actions must take place in relation to each other?
- What control measures do I need to impose?

The concepts introduced here are of a general nature and are introductory to many specific activities of the project like cognitive engineering, knowledge engineering, software engineering and experimentation design to name a few. They also must be refined into detailed scenarios (scripts of events likely to happen) for every stakeholder of the project to consider. This helps situate the SASS in its "natural" environment for which it performs the best.

3.2 Situation Awareness and Analysis

Though we introduced the concept of Situation Awareness (SAW) and Situation Analysis (SA), we did not provide any definition. A more substantial presentation of SAW and SA is given in [5], and the gist of it is reproduced herein.

Endsley [10] proposed a general definition of situation awareness that has been found to be applicable across a wide variety of domains. She describes SAW as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future. This is illustrated in Figure 2.

In her model, Endsley presented situation awareness as a stage separate from decision making (DM) and action. SAW is described as the decision maker's internal, mental model of the state of the environment. Based on that representation, the decision maker can decide what to do about the situation and carry out any necessary actions. There is thus a strong link between SAW and the DM processes. SAW is represented as the main precursor to decision making. This is illustrated in Figure 3, built around Boyd's OODA loop.

In this perspective, Roy [11] proposed the concept of Situation Analysis (SA) in an attempt to merge the data fusion and situation awareness models. He defines situation analysis as a process, the examination of a situation, its elements, and their relations, to provide and maintain a product, i.e., a state of situation awareness, for the decision maker.

Figure 3: Situation Analysis

While SAW is a state of cognition, SA is the process by which one gains this state. SATAC therefore aims at supporting and improving the SA process by providing an appropriate set of tools termed *Situation Analysis Support System (SASS)*.

3.3 Towards a Knowledge-based Situation Analysis Support System

Fully describing a SASS is out of the scope of this paper. Its details can be found in [6]. We simply reproduce and briefly explain its conceptual diagram. In Figure 4, we see that situation analysis draws upon two well-known operational processes: The Intelligence and Command and Control cycles. SA as a process leads to SAW constituted by some knowledge of a situation and derived information or data. Also, SA puts to work some notions of fusion (involving sub-processes like Alignment of information, association and the fusion process per se) and some mechanisms of inferencing to derive new information. These aspects (colored in blue) are to be formalized in such a way that they can be manipulated by a machine, that is:

- Knowledge engineering aims at formalizing the knowledge of a domain expert;
- Ontological engineering aims at formalizing and structuring the information shared by agents in a given domain;
- Fusion (and its sub processes) is formalized through specific and specialized algorithms;
- Inferencing is formalized through mathematics (First-order logic, propositional calculus, etc).

Finally, careful considerations must be made to take into account the inherent uncertainty that underpins every aspect of SAW.

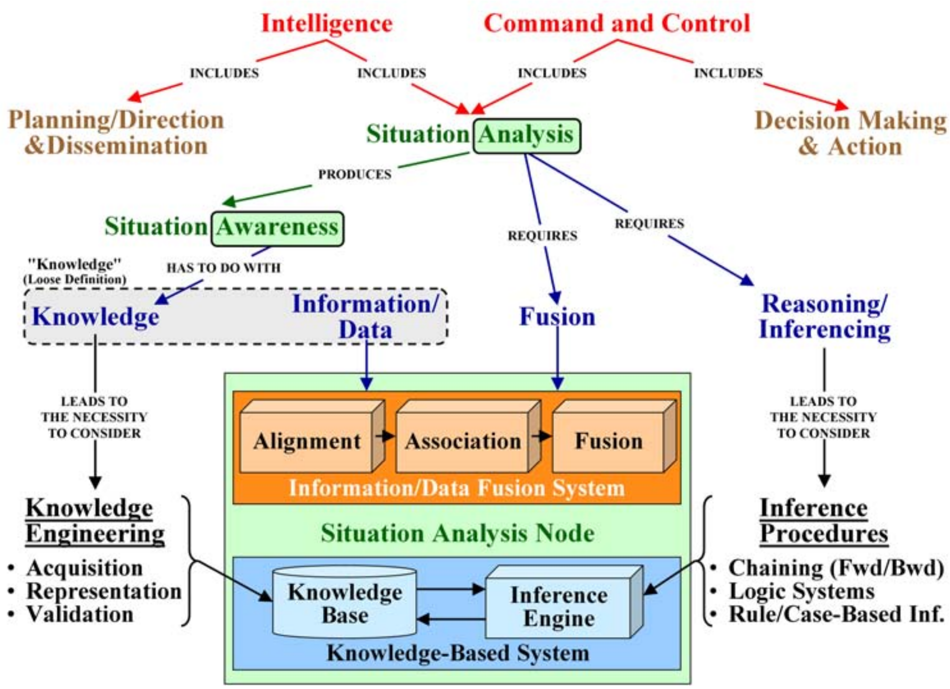

Figure 4: Information Fusion and Knowledge-based System to Support Situation Analysis

These activities enable the building of components that constitute a knowledge-based system specifically designed to support SA, namely, a SASS.

3.4 A Holistic R&D Framework for Knowledge-Based SA Support Systems

The overall development of a SASS covers a wide range of activities. It is important that we orchestrate the conduct of these activities into what we will call a holistic R&D framework for knowledge-based SASSs [6]. This framework depicted in Figure 5 is briefly described in this section.

The framework is divided into four distinct phases:

- Understand the Application Domain,
- Develop Support System Capabilities,
- Evaluation in Laboratory, Testbed(s) with Modeling and Simulation,
- Field Demonstration(s) and Experimentation.

These phases, from left to right in the figure, are scaled in time (Experimentation necessarily takes place after the system was built!). However, it is good engineering practice to

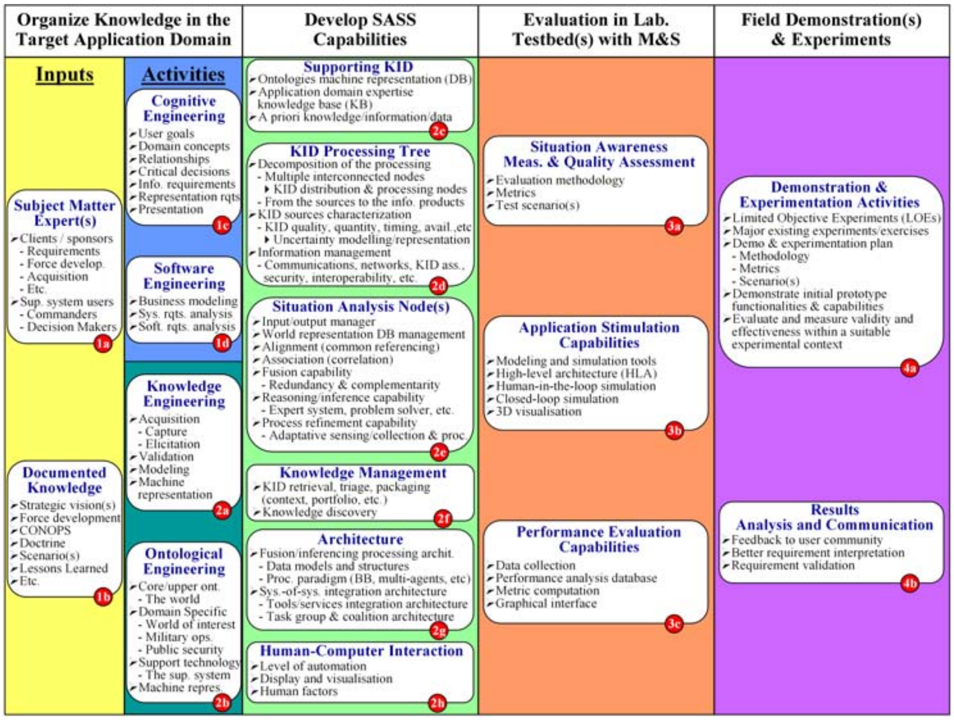

Figure 5: A Holistic Framework for Building Knowledge-Based SASSs

"loop" several times from design to testing in small steps and in an incremental manner. For example, one could focus on the development of a single sub-component of the SASS and go through with testing in order to validate its performance and effectiveness. SATAC shall adopt this approach.

Each of the four blocks regroups several activities that are of relevance to the development of a SASS. While SATAC will try to reasonably cover the extent of these activities, one must understand that most of them correspond to a field of research. SATAC has no claim in digging in all these areas, but to tackle enough of them so that the resulting "product" is operationally relevant to the Army (see discussion in section 1.5). Still, we hope as scientists to deepen and strengthen our knowledge of some of these subjects. As such, these activities will be categorized into what we will call SATAC's main R&D focus activities.

3.5 SATAC R&D Focus Activities

SATAC's R&D focus activities are those of particular interest to this project. They constitute what has been identified as capability gaps for the Army. Advancement in these subjects, we believe, would help them significantly. These gaps also happen to correspond to some achievements we had in the past with other clients (e.g. the Navy) or for which we recently developed/gained expertise (e.g. ontological engineering). This section enumerates and briefly describes two of these subject areas. It must be noted that this list is not exhaustive nor is it restricted to these topics since SATAC, throughout its lifetime, may gain the participation of other scientists proficient in their domain. This list would then grow.

3.5.1 Automated Reasoning

Since 1996, the Army has put significant efforts in developing a semi-formal ontology for its operations with coalition partners. This effort, now known as the Multilateral Interoperability Programme (MIP), led to the development of the Joint, Consultation, Command and Control Information Exchange Data Model (JC3IEDM) [12]. The Army develops a system of systems that draws upon this ontology. However, as of today, its exploitation has been limited to straightforward interactions with its instance database for display purposes. Not that this is a simple matter on the contrary, but such a repository for structured information offers much more.

For one thing, the structured information in an instance database of the JC3IEDM enables the formation of propositions or sentences for which the semantics are well established. If truth values are attached to these sentences, one can use them in propositional or sentential logic. This can in turn be implemented into a machine, thus offering a capability for automated reasoning which is one of the requirements to support SA.

3.5.2 Cognitive Engineering

Software engineering methodologies have this tendency to jump a bit too quickly into the specification of software requirements. Even these methodologies recognizing the importance of linking software requirements to user needs (e.g. Rational Unified Process (RUP), Reference Model - Open Distributed Processing (RM-ODP), IEEE 12207, etc) tend to overlook cognitive affordance, that is, the facility with which a human will work with the system. SATAC addresses the Tactical Army Commander on the aspect of Situation Awareness which is something that is profoundly human in essence. Therefore, there is a strong need to understand how such an expert thinks and solves problems in the type of situation he deals with.

Another key benefit of this activity is to leave our client, the Directorate of Land Requirements (DLR), with a sense of the activities they should conduct when they formulate requirements. Indeed, DLR often proposes software requirements to their clients as an end product (*The system shall...*) with little or no links to what human needs derived these requirements. They handle the traceability aspects between software requirements quite well, but not so well between cognitive aspects and system aspects. We believe that this cognitive engineering effort we will undertake in SATAC will help them understand the issues involved and the kind of resources needed to realize it.

4 Conclusion

Proper information management is key to ascertain dominance of the Canadian Army in the conduct of its operations. Not only should it be able to handle correctly the information that is available at any given time, but it should also be able to obtain new information that is logically derivable in an automated way. This is known as automated reasoning. Project SATAC's objective is to give the Canadian Army the means to build an automated reasoning capability in order to support Situation Analysis, a process by which the human gains Situation Awareness.

To achieve its goal, SATAC will apply, to the extent possible, the principles enumerated in its holistic framework in order to build the components of a Situation Analysis Support System. These principles aggregate the known best practices of several fields of computer science such as cognitive engineering, software engineering, knowledge engineering and ontological engineering to name but a few.

SATAC's approach to mitigate the complexity of its approach is to seek a balance between breadth and depth. That is, SATAC will try to cover a fair number of activities while digging deeper into a few selected ones. The first helps situate the project in the Army's IT spectrum while the latter maximises the probability of scientific discoveries.

Finally, we hope that the SATAC project will, in the end, leave DRDC with a consistent and sufficient enough body of knowledge to sustain other R&D initiatives.

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Annex A: List of Acronyms

AI	Artificial Intelligence
ARP	Applied Research Project
AS	Analyse de la Situation
ASCAT	Analyse de la Situation pour le Commandant d'Armée de terre Tactique
BG	Battle Group
C2	Command and Control
C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command and Control Information System
C4ISR	Command, Control, Computers, Communications, Intelligence, Surveillance and Reconnaissance
COA	Course of Action
COIN	Counter Insurgency Operations
DLR	Directorate of Land Requirements
DM	Decision Making
DND	Department of National Defence
EBO	Effects-Based Operations
IT	Information Technologies
DRDC	Defence Research and Development Canada
FSO	Full-Spectrum Operations
GCCS	Global Command and Control System
IEEE	Institute of Electrical and Electronics Engineers
JC3IEDM	Joint Consultation Command and Control Information Exchange Data Model
LIC	Low-Intensity Conflict
MIP	Multilateral Interoperability Programme
MoE	Measure of Effectiveness
MoM	Measure of Merit
MOOTW	Military Operations Other-Than-War
MoP	Measure of Performance
NATO	North Atlantic Treaty Organization
OODA	Observe-Orient-Decide-Act
OPP	Operational Planning Process
PRA	Projet de Recherche Appliqué
R&D	Research and Development
RM-ODP	Reference Model - Open Distributed Processing
RUP	Rational Unified Process
S&T	Science and Technology
SA	Situation Analysis
SAIF	Situation Analysis and Information Fusion

SASO	Stability and Support Operations
SASS	Situation Analysis Support System
SAW	Situation Awareness
SATAC	Situation Analysis for the Tactical Army Commander
SME	Subject-Matter Expert
TAC	Tactical Army Commander
TDP	Technical Demonstration Program

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We present the project SATAC (Situation Analysis for the Tactical Army Commander). The goal of this project is to give the Canadian Army the means to build an automated reasoning capability in order to support Situation Analysis, a process by which the human gains Situation Awareness (SA). We explain our general approach to address these problems we have identified to be of interest to our client, the Directorate of Land Requirements (DLR).

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