Towards Optimized Performance in Military Operations

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***Abstract*—Succeeding in military operations requires that the available resources be timely assessed and optimized. Sustaining combat performance asks for suitable tools for organizing services and resources that allow drawing from Situational Awareness, Common Operational Picture and utilizing Graphic User Interfaces. When aiming at maximum impact with the resources available, Service Oriented Architecture (SOA) can be used as a tool in the process of organizing the services. This paper presents an idea-phase introduction of how to facilitate military decision-making process with the assistance of the systems described here. The objective involves increasing the performance capability to allow time-efficient execution of military operations. The paper examines the optimization of services requested by means of SOA when viewing a military maneuver as a Business Process (BP) and sketches a preliminary Grid for Interface Assisted Decision Making (GIADM) to facilitate timely and accurate data processing. GIADM exploits the data offered by means of SOA, the Resource Manager (RM), and BP, and aims at facilitating the decision making process of a military commander at the planning stage of a given operation including evaluating Courses of Action (COA). The paper sets out to identify how to utilize the collected data from the battlespace to empower the process of decision-making and how to benefit from SOA in the creation process of Grid for Interface Assisted Decision Making.**

Keywords-Grid for Interface Assisted Decision Making, Business Process, military operation, Resource Manager, Service Oriented Architecture.

I. INTRODUCTION

Requiring the optimization of the resources available, any military maneuver, including the dismounted company attack, serves as an example of a military operation in which the optimization of resources is the key to success [1]. This paper uses dismounted company attack as an example of a process that requires the constant ability to transmit relevant data and allocate requested services. In military operations, the destruction of mechanical and electrical adversaries continues to be necessary. Material destruction focuses on the enemy's manpower and machinery, when electronically performed destruction can be understood as deleting the adversary's capability to use electronic devices.

The asymmetric nature of war requires improved capabilities in allocating the resources available. This sets increasing demands for Situational Awareness (SA), the data necessary for commanders executing operations in the battle space: precise data concerning location information, updated data involving performance capabilities of own troops and their current operation status.

This paper examines the optimization of services requested by means of SOA when viewing a military maneuver as a Business Process and discusses a possible method for organizing the distribution of requested services in light of the set of assisting tools available real-time. Although these types of systems tend to be based on classified data, this paper exclusively relies on public domain sources.

This paper argues that even though the requested services can be processed with the described tools (Resource Manager and Scheduler) and outlined methods of organizing services (Business Process –like actions assisted with SOA), the system still remains incomplete because it lacks a key tool, a field-tested grid that would take into account all the relevant and constantly changing variables, such as the planned duration of an operation, the type of terrain where the operation is taking place, the expected troop performance and the capabilities of a specific military unit. None of the expected performance or capability values have been determined, evaluated or inserted as part of any Battle Management System. This paper sketches the idea of a Grid for Interface Assisted Decision Making (GIADM) to facilitate timely and accurate data processing.

Military commanders depend on automatic data collecting processes and tools to simplify complicated military maneuvers. To optimize performance, a military operation, an attack, can be simplified in the form of a Business Process (BP) by means of Service Oriented Architecture (SOA). The element named Resource Manager is a tool to be used in managing and allocating the existing resources. A BP -like orchestration of systems and services may improve the overall performance of military operations executed. This may result in improved overall performance capabilities while executing missions in the battlespace benefitting from SOA, the RM and the Scheduler [1].

Comparing modeling war as a process assisted with Service Oriented Architecture with other types of approaches would be difficult, as these types of models tend to be labeled as classified data. Hence, comparing different models remains outside the scope of this paper. Consequently, the details concerning network topology and energy supply are excluded from this paper as well.

The military objectives concerning digitizing dismounted soldiers, sensing their environment and sharing information, will likely require as much as twice the power required by soldiers today [2]. Issues related to power usage remain outside the scope of this study for the reasons stated above.

This paper is organized as follows: Section II introduces the related work, Section III discusses the Military Operation as a process, Section IV deals with Service Oriented Architecture and the allocation of requested services, and Section V examines a maneuver, a dismounted company attack, as a Business Process. Section VI combines the Business Process and the Resource Manager. Section VII explains the significance of communication and networks in the process of war, and Section VIII discusses the use of Unmanned Vehicles (UVs) and Section IX introduces a Grid for Interface Assisted Decision Making (GIADM). Section X concentrates on the Graphic User Interface (GUI). Section XI discusses on security and the Scheduler and Section XII concentrates on benefits and drawbacks of the introduced system. Section XIII concludes the paper with Section XIV suggesting further work.

II. Related Work

Since the existence and utilization of military troops, the necessity to improve the performance of soldiers and overall military performance has loomed large. This translates into the survival of the fittest. As we speak, in the era of Information Technology and beyond, the need to use advanced electrical devices to gain increased military performance has become a military research and development stable. When different types of Battle Management Systems have been applied to assist in using weapon systems, the performance of these Battle Management Systems have been linked to command and control systems to facilitate automated decision making.

In the field of command and control, the need for Artificial Intelligence has been recognized from the perspective of modeling command and control [3]. As noted in [4], command and control increasingly necessitates the use of automated decision assistants and automated decision makers to aid in executing the complex and dynamic operations performed in the battlespace. The presented blueprint in [4] also provides design guidance for resource management.

As explained in [5], a new method of firepower allocation is presented, which uses the structure of Multi-Agent system to boost the firepower application as a process. Also a Multi-Agent System (MAS) in Computer Generated Forces (CGF) has been discussed in [6] in an environment of Tank combat unit. In [6] the hierarchical CGF agent model is designed to support the planning and execution of different tasks. Furthermore, a modeling method of agent-based Computer Generated Forces is discussed in [7] and a flowcart of simulation process has been created complemented by architecture on the combat simulation model.

As discussed in [8], it is necessary to support commanders' continuous access to information and to automate the Military Decision-Making Process (MDMP). As [8] describes, with the use of the computational model R-CAST, cognitive agents can effectively assist the commander and thus bring about improved cognitive performance in military decision making tasks.

Service Oriented Architecture (SOA) can be identified as a central factor in military environment, especially in creating capabilities. As identified in [9], SOA can be useful in providing required capabilities for the military in the needs concerning command, control, communications, computers, intelligence, information, surveillance and reconnaissance (C^4I^2SR). SOA can assist in gaining increased capabilities in Situational Awareness, improved Qulity of Service (QoS) and in decision making process. Soldier's overall performance remains critical. As described in [10], soldiers' performance has been studied by means of creating a map featuring a Bayesian Soldier Performance Model. The importance of the performance of a single soldier can never be over emphasized from the perspective of a military operation.

The papers referred to above leave outside their scope the orchestration and allocation of services in the battlespace, such as processing fire support orders, requesting evacuation, and gaining information from designated areas. Moreover, these papers leave outside their scope the military performance capability offered for both a soldier and a military unit with the assistance of SOA. This requires that SOA be properly connected with the executing processes of a military operation. In addition, thre is room in the existing discussion for examining the use of Unmanned Vehicles as robotic platforms for communication purposes.

This paper views a military operation as a Business Process. The use of SOA has been introduced together with possible services to be orchestrated and allocated as listed in the previous paragraph. Also, a Resource Manager and its functions have been introduced and combined with Business Processes and SOA. This paper emphasizes the significance of ubiquitous communication services and a reliable, operationally secure network system in executing military operations. Soldiers' performance has been evaluated with the assistance of Psycho Physical Factor. The formula used is linked to commanding troops (identified as nodes) in a military operation. A new tool to assist commander's decision making process has been introduced. The tool is named Grid for Interface Assisted Decision Making (GIADM) The paper offers a perspective for comprehending the complexity of executing a military process.

III. Military Operation as a Process

Operating in military settings relies on the existing resources available real-time. These existing military resources can be understood as comprising troops or units (personnel), logistics (resupply materiel, medical supplies) and heavy machinery (tanks, armored vehicles), ammunition (cartridges, shells) and services (transportation, resupply, evacuation). These resources have to be available and accessible when executing a military operation. War can be modeled as a Business Process and Service Oriented Architecture (SOA) can used as an assistant in military operations, as described in [11]. Military operations are composed of parts, such as Information Management, which is linked with Network operations connected to Network

Centric Warfare (NCW). NCW adopts the characteristics of modern age into the military battlespace, especially when applying SOA in issues concerning battlespace Situational Awareness [12]. As communication systems remain vital in executing military processes of any kind, a functional and reliable communication network system ensures that issues related to Situation Awareness (SA) and Common Operational Picture (COP) can be tackled. The following Figure 1 displays communication systems related to Information Management and Network Operations.

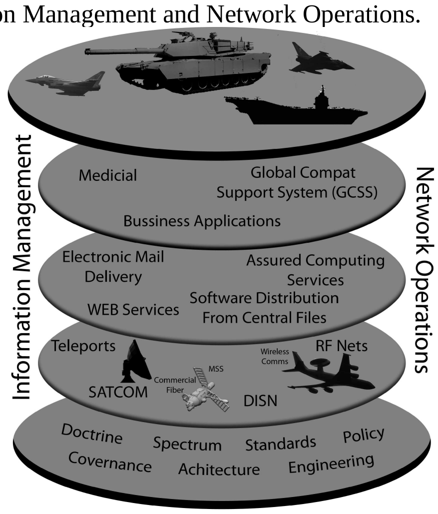

Figure 1. Relation of Information Management and Network Operations.

When applying the Business Process approach to Service Oriented Architecture, the services available are viewed as corresponding with existing real resources. These real resources can be more easily understood as services produced by the military troops themselves or by neighboring troops or services being served from the higher echelon. These services can be seen, for instance, as maintenance of machinery, close-air support (CAS), evacuation and resupply.

The typical military operation carried out by a dismounted company is an attack maneuver. A dismounted company attack is composed of the actions performed by the company itself, as well as services offered by a higher echelon. A dismounted company attack is performed by using personnel (soldiers) equipped with personal weapons and heavy machinery (trucks, armored personnel carriers, artillery). A dismounted company attack is illustrated in Figure 2.

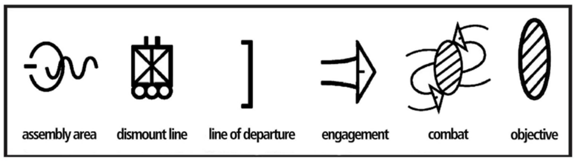

Figure 2. Dismounted Company attack as a process.

A planned dismounted attack usually starts from the assembly area, moves on to the dismount line, via a line of departure, advances to engagement, results in close combat and ends when the set objective is reached. The SOA BP approach can increase the probability of success of an attack by empowering the human-based decision-making process with computers. This can enable an optimal use of resources, and thereby improve overall performance in operations.

A successful military operation requires coordination and timing of existing resources. The availability of real resources in a given place and time is limited and needs to be meticulously scheduled. Usually, SOA services are assumed to be independent of each other but this assumption is no longer valid if SOA services represent real existing resources. The Resource Manager is a necessary element in SOA architecture as discussed in [1]. In the case of a dismounted company attack, successful performance requires that the requested services, for instance, processing a fire support order, are allocated timely and accurately. This sets demands for enhanced Situational Awareness. In the utilization of SOA in military operations, challenges of real-time SOA must be solved [1]. To successfully execute BPs, the Business Process Execution Language (BPEL) is required, as argued in [13].

Organizing of troops and making decisions concerning weapon selection equals a process, in which automation is needed. Situations alter rapidly in the battlespace. Human capabilities are very limited as regards simultaneously monitoring different sensors, a number of screens and communicating with all the decision makers while executing commands. All the matters concerning Computers, Command, Control, Communication, Intelligence, Information, Surveillance and Reconnaissance (C4I2SR) and involving targeting and weapon systems by default value tend to change rapidly and, obviously, any change in one system can result in an immediate change in another system. An example of this would be a weapon system with the effective range of 5000 meters. When a targeting system recognizes the potential target at 7000 meters, locks into the potential target at this distance and transmits the data to the decision maker, the target has already travelled possibly several kilometers before the command for executing the firing mission arrives. By the time the firing order is executed, the target can be out of range of the weapon system (which was the set 5000 said), depending on the target's pace. Therefore, automation is needed, but only to an extent; otherwise, own or friendly aerial targets may get annihilated. This decision making process when applying targeting and weapon systems is also affected by matters concerning Situational Awareness and Common Operational Picture as described in Figure 3.

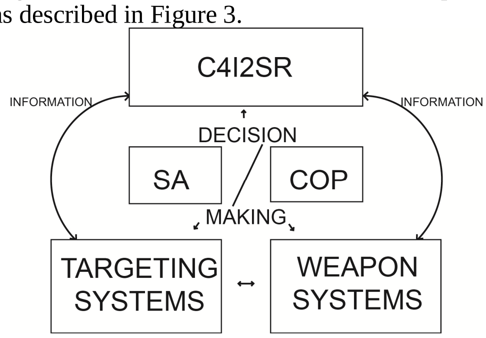

Figure 3. Decision making in applying targeting and weapon systems.

IV. SERVICE ORIENTED ARCHITECTURE AND SERVICES

To utilize Service Oriented Architecture in a military operation, its capabilities and nature need to be comprehended and to be aware of the services available to organize the system to support a military operation, such as a dismounted company attack.

When needing to affect the sequencing and pace of events in the name of increasing efficiency, SOA is needed as an accelerator. In a successful military operation assisted with SOA, the end result can be seen as an operation with a minimum amount of collateral damage and fratricide. Moreover, a successful operation can be seen as efficient use of resources (ammunition, troops, vehicles, medical support and time). Thereby SOA is viewed as an aid for a military commander in the decision making process, for instance, when choosing Courses of Actions (COAs). Figure 4 depicts an example of two different types of COAs in the battlespace. In the first COA, the objective is to stop an armored enemy, whereas in the second COA, the objective is to destroy a Command Post.

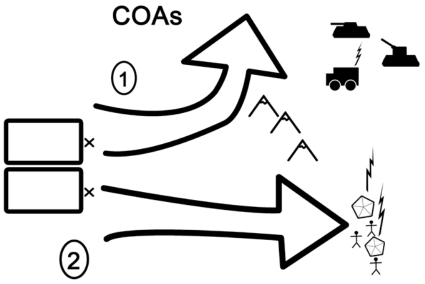

Figure 4. Different types of Courses of Actions.

SOA enables organizations and entities to operate complicated systems and enhance interoperability, collaboration, see [1], and foster the reusing of components and interfaces. SOA can be used in service collaboration. With the correct framework, SOA allows publishing services in a service registry and exchanging data through the Simple Object Access Protocol (SOAP) [13]. SOA offers an adjustable solution for systems integration, applications, protocols, data sources and processes to form a cohesive system that supports the execution of critical BPs [2]. SOA can be used as a collaboration tool in crises management and military environments if the challenges of real-time SOA [14] are solved.

In order to successfully execute BPs, the Business Process Execution Language (BPEL) is required, as argued in [11]. In military systems, the adoption of SOA principles can beneficially result in the overall improvement of system flexibility and maintenance. SOA provides the user with richer information sets via the ability of Web Services to reach out through the networks, see [15]. In the process of achieving greater interoperability, SOA can be used by utilizing service oriented migration and reuse technique, described in [16].

In Network Centric Warfare contexts, SOA has been recognized to act as an enabler of services. SOA is an architecture style that encourages loose coupling between services to facilitate interoperability and the reuse of existing resources as described in [17]. SOA is seen as a tool in enabling agility to handle the changing dynamic evolution needed in network enabled capability, see [18]. The concept of NCW can be viewed as an integration of assets to meet a mission objective, as discussed in [18]. NCW fosters SOA to achieve flexible forces, which are constantly ready and deployable, capable of dynamic changes and evolution to achieve realizable effects. To benefit from SOA in an optimal way, organizations require a comprehensive and applicable SOA governance framework to implement the management and control mechanisms in the system, as argued in [19].

It has been pointed out [20] that Shared SA is in central role for network-enabled capabilities, as described in [20]. In NEC, SOA is most commonly realized through Web Services' GUIs, as discussed in [21], using Extensible Markup Language (XML) formatted documents, see [20]. As evident, XML WS have been recently used to implement SOA enabling the building of BPs by dynamically calling services from the World Wide Web.

SOA is an open concept and supports plug-and-play capabilities of heterogeneous software and hardware components, with the implementation of Web Services, which is probably so far the most popular implementation of SOA, as discussed in [22]. For this reason, SOA has been selected as the architectural solution for the C4I2SR systems for the Finnish Defence Forces [23]. SOA is seen as an enabler in crises management organizations for delivering data and services across political, organizational and cultural boundaries as well as addressing the issues of information sharing regardless of where required data is stored, as concluded in [24]. The global information grid is an essential vehicle in the execution of SOA and for the transformation of data.

In tactical operations, the significance of the real-time location data plays an important role. The tools available include different types of Tactical Battle Management Systems (BMS) for dismounted combat to produce the location information of own troops and precise target designation. The tools for target designation and air-land coordination are necessary requirements for success in operations as described in [25]. Furthermore, air-to-ground communications are described in [26].

Requirements related to improved Situational Awareness, communications and networks are described in [27], grid computing in the battlespace plays an important role as described in [28], and enhancing squad communications with the assistance of smart phones is described in [29]. Lastly, multiplication of various technologies is introduced in [30]. Their overall purpose is to increase the performance of a Future Force Warrior. The inputs of all these tools and networks can be calculated with the assistance of tools used in Business Processes and with the assistance of Service Oriented Architecture.

There has to be a carefully defined military operation before SOA can be adopted in a specific process. The planning sequence requires modeling the military operation into small fragments and the relations and functions between different fragments have to be planned. Moreover, parts and functions of Business Processes have to be opened and studied before embedding SOA into BP by examining the necessary services and their features.

The variety of services used in BPs may be in the operational use of a single unit or several units at the same time. This requires an efficient orchestration of services to maintain service control. SOA can be seen as an enabler in the process of executing military operations as BPs.

The offered services during an advancing dismounted attack are listed in Table I. Most of these services can be pre-programmed to concern the wanted product-line Future Force Warrior (FFW) level. The company commander utilizes various services (fire support orders, location services, medical care, resupply, evacuation, geographical information system -map-service, Blue Force Tracking) while executing the commanded attack from the assembly area to the objective. Table I illustrates possible services available for a dismounted company attack.

TABLE I. LIST OF PRE-PROGRAMMED AND ADDITIONAL SERVICES IN A DISMOUNTED COMPANY ATTACK.

Area of dismounted attack		*Basic services for the Warriors*	*Advanced services (platoon leaders and above)*
1	Assembly area	Location data, terminal guidance to the dismount line	Blue Force data, evacuation
2	Dismount line	Blue Force data, evacuation, resupply	Blue Force data, evacuation
3	Line of departure	Blue Force data, evacuation, resupply	Precision location data, fire support
4	Engagement	Precision location data, fire support	Air-strike
5	Combat	Reinforcement, evacuation, resupply	Air-strike, preparing instructions to the following mission
6	Objective	Evacuation, resupply, reinforcement, precise location data	Air-strike, next mission objective and its time-frame

Fulfilling a requested service asks for the requested service to be available and within range. When dealing with Fire Support Orders (FSO), the range limitations of artillery units are critical. An artillery unit has to be located within appropriate range, and it has to be ready to intake Fire Support Orders and execute them in the required time frame, precisely as ordered.

In a military operation, it is important both to optimize the resources and also minimize collateral damage. SOA can act as a functioning part of the weapon selection process, especially in offering the weapons available for the use of a company commander. Figure 5 indicates the caption from a Battle Management System from a target rich environment. The mission is to destroy the enemy and simultaneously minimize fratricide and collateral damage.

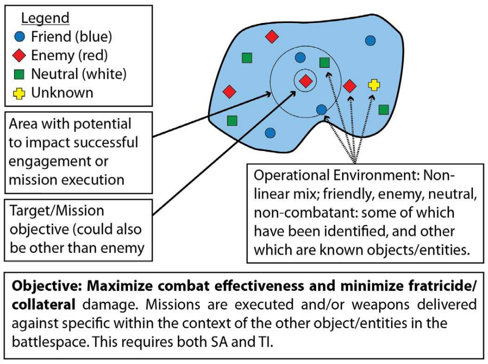

Figure 5. Challenges in weapon selection process.

Battle Management Systems are strongly linked to Command and Control systems. Typically Command and Control systems provide support for Battle Management Systems in various tasks, such as operational planning, obtaining Situational Awareness, creating Common Operational Picture and sustaining the decision making process. The goal of Command and Control systems is to increase the operational capabilities of the operating units from the battalion level to a single platform and soldier level [31].

When we observe the possibilities to fuse the information, Battle Management Systems are usable to an extent. Battle Management Systems use Battle Management Language (BML), which also enables automatic information fusion, as discussed in [32]. As BML represents an unambiguous language for military communication, it is a usable tool in a digitized battlespace environment. As described in [32], the vocabulary of BML is based on a Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM). Several versions of BML are available to meet the requirements of a consumer for different purposes.

Military commanders need to process a vast amount of data for decision making purposes. The formula to calculate the cumulative uncertainty can be found in [32]. This formula produces a result, which still has to be evaluated by a human being. The significance of a human-being in a decision loop continues to be indispensable. Digitized tools need to be utilized especially in the planning stage of an operation.

V. BUSINESS PROCESS

The orchestration of Business Processes requires a tool for allocating resources, the Resource Manager (RM). The tool has been described in [33]. The RM sorts out and lines up the requested services. These requested services can be understood as service actions performed or produced by humans or machines, involving transportation, issuing Fire Support Orders or evacuation. Furthermore, a single service can be understood as a data exchange process. As militaries implement the framework of Network Centric Warfare with a continuing need to automate the command and control (C2) tools utilized in military, the tempo of operations must be taken into consideration. The collected data need to be processed, analyzed, verified, transmitted, and finally stored. SOA can be identified as a technology that can satisfy these needs of network centric operations. The starting point in the BP approach to SOA is that the main business operations of the organization are described by SOA BPs. The Business Processes are chains of logic that request SOA services. In the case of a military setting, the Business Processes represent military operations as depicted in Figure 6.

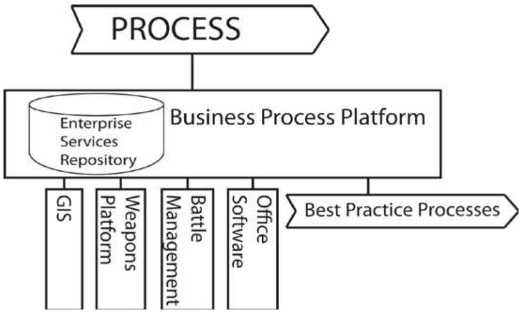

Figure 6. Busines Process Platform as a service enabler.

SOA can be utilized in reorganizing the military organization when casualties affect the command chains of the military organization. This is described in [34]. In Network Centric Warfare one key aspect is to offer a valid and accurate Common Operational Picture (COP) for the operating troops in the battlespace. A basic requirement for a combat leader is to have a possibility to lead the troops and gain good COP. An important aspect in distributing information in the battlespace is the amount and quality of information shared at different levels. A squad leader needs only basic information of the task while the battalion leader needs the information in a much wider scope and rearranged. The amount of information allocated needs to be set to a level where the person responsible for making decisions is able to perform timely and make accurate decisions.

SOA offers a way to organize this system in the form of versatile and varying types of processes and services. One terminal can use a number of services over a network to gain the information needed. All the terminals also act as services themselves and this creates a network of various services. The strong point of this system is that it is not dependent on any node of the system and in ideal case every terminal can change the current level. Each Warrior type has to be able to act as a leader at the next hierarchy level. For example, a Basic Warrior has the capability to act as a squad leader if needed. The terminals are also able to discover the services dynamically, which is an important aspect in a versatile and changing system in the form of databases and UDDI - registries to each node.

A constructive idea in SOA is its process ideology. In a military system the composition of the unit together with its performance are in a key role in executing the operations. Military units suffer from casualties and their performance value tends to change in an unpredictable manner. A military organization can be described at different abstraction levels seen in Figure 7.

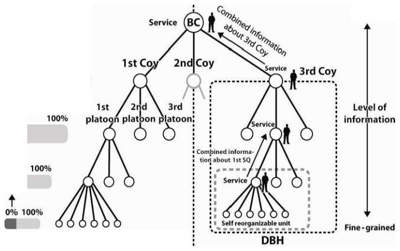

Figure 7. Overall view of Dynamic Hierarchy in a military organization.

Psycho Physical Factor can be calculated by using varying and measured variables of individuals' physical state. These values can be identified as, for example, heart rate, sweep of sweat and hormonal activity. Creating this factor is described in [26] and the formula can be useful in calculating the performance of a military unit. Varying variables can be measured via a wrist embedded computer. Obviously, to gain reliable values of each soldier and his or her current state of health, a monitoring period of at least six months is required in advance before starting field tests. Figure 8 features the formula created in [34], which describe calculating Psycho Physical Factor and accounts for command and control relations in a military organization.

As demonstrated in [9], human variables are important in the quest for answers to improve the soldier performance, including the measuring of stress, sleep deprivation, fatique and mental and physical trauma together with information overload, mission duration and overall energy balance. In [9] the Bayesian network model of Soldier performance was utilized. In addition, the formula for Psycho Physical Factor is relevant when calculating the performance values for military units and organizations varying in size (team, platoon, company, battalion). Here the Dynamic Battlefield Hierarchy plays an important role.

Figure 9 represents the increasing abstraction level in Dynamic Battlefield Hierarchy. Dynamic Battlefield Hierarchy is utilized in organizing and re-organizing military units. The performance of soldiers can be calculated, and as a result, the performance level of a whole military unit can be determined. When the performance is calculated, this value can be inserted as a mathematical value into different types of decision making processes. The following Figure 9 introduces a simplified view of the performance of a single military unit. In this figure the stress level of each soldier has been taken into consideration as well as the number of battles they have encountered and participated. Their recovery times have been calculated together with the stress level and the level of missing soldiers from the organization. As a result, each military unit (team, platoon, company, and battalion) can be identified with a performance value. The required power for each attack can be calculated beforehand once the enemy has been assessed first (the number of soldiers and amount of weaponry). The system described in Figure 8 was validated and laboratory tested as described in [34].

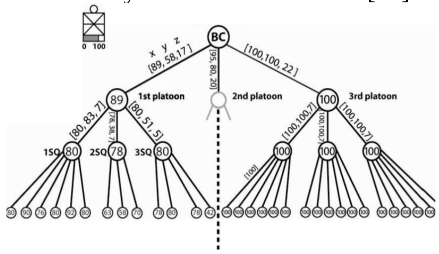

Figure 8. Calculating the performance of a military unit [27].

VI. BUSINESS PROCESS AND RESOURCE MANAGER

The orchestration of Business Processes requires a tool for allocating resources, the Resource Manager (RM). The tool has been described in [33]. The RM sorts out and lines up the requested services. As militaries implement the framework of Network Centric Warfare with a continuing need to automate the Command and Control (C2) tools utilized in military, the ever-increasing tempo of operations must be taken into consideration. The collected data need to be processed, analyzed, verified, transmitted, and finally stored. SOA can be identified as a technology that can satisfy these needs of network centric operations. The starting point in the BP approach to SOA is that the main business operations of the organization are described by SOA BPs. The Business Processes are chains of logic that request SOA services. As regards military settings, the Business Processes represent military operations as explained earlier and depicted in Figure 6.

SOA-technology involves assisting, planning and executing events performed in military operations. Business processes are executed on a specific Business Process platform. Services and platforms, including geographical information-services, weapons platforms, and Battle Management Systems, are linked to the Business Process Platform to obtain optimal results. When a Future Force Warrior can benefit from the possibilities offered by a successful adoption of BP and SOA, the result can be improved overall performance in military operations.

Figure 9 describes how the Business Process approach can improve the performance of an FFW. Several battlefield sensors gather data from the battlespace. The collected data are then automatically transmitted to be analyzed in a command post. Various battlefield sensors transmit data to a context-aware reasoning layer. In this layer, data are converted to context and an inference engine transmits the data to a ubiquitous main layer for analyzing purposes. The data are verified, analyzed and transmitted as information for the execution of the operation.

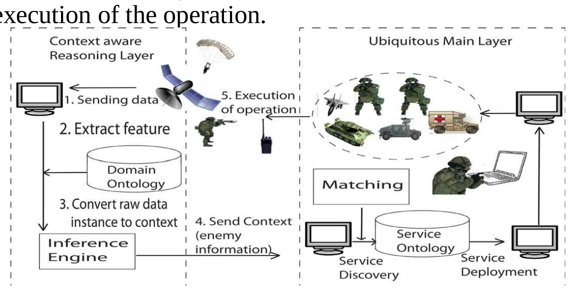

Figure 9. Increased FFW Performance can be gained via successful data utilization and analyzing processes.

Several of the needed services require real-time resources. These services can be identified, for example, as collecting SA data and issuing Fire Support Orders. Thus, the services and their use must be scheduled and sequenced to sustain the processes. The RM sorts out and lines up simultaneous requests concerning the requested service. The RM serves as the element, which provides the needed services for User Groups (UGs). Services can be either pre-programmed on demand or be available on request basis. The RM as a tool is located at the battalion level. The user groups send a request for the demanded service. The UGs are then authenticated, their privileges verified, after which the request is transmitted to the RM. The key functions of the RM are: 1) to receive the request of a required service, 2) to organize the line of user groups in the correct order depending on the UGs' privileges and battle-situation, 3) to check whether the service is available and within range, 4) to provide the User Groups with the answer, which is either the requested service or a rejection of the service.

The RM functions as a fully automated chain of functions in certain processes [33]. The key function of the person in the loop is to monitor the flow of events and to interfere with the chain of events if an unpredicted anomaly occurs in the process. As the RM is a critical resource, it must be physically protected against enemy actions.

The role of the RM is central in the allocating of resources in the BP. The RM communicates with four intermodules. The RM graphical user interface provides the core interface between all the presented modules and the Local Area Network (LAN), as shown in Figure 10. The LAN is utilized as a battlefield network or a community network as it can be used in a wide area of networks. However, the sharing of networking environment and its resources remains challenging in that searching for information and asking for resources turn out to be challenging when lacking proper search mechanisms. Each module has pre-defined and precise functions. First, the file and resources sharing module communicates with the RM GUI in conjunction with the sharing and the download module. The file and resource transfer and download module supports and enables the transfer or download of the searched file or resource from the other node connected to the network. The shared files and resources are listed on the RM GUI, where the listed and downloaded files can be examined. It is obvious that the same identified services are requested simultaneously. Therefore, the composition of the RM needs to be stable and reliable. Figure 10 illustrates the composition and function of the RM.

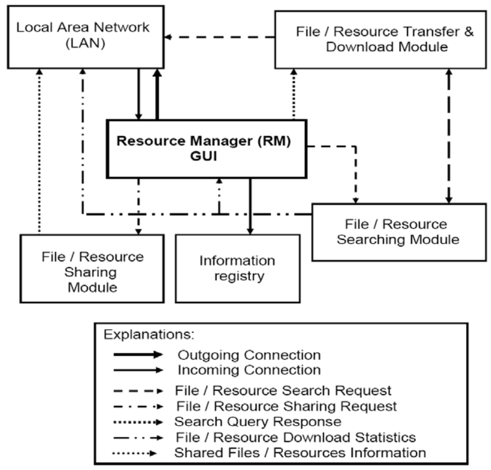

Figure 10. The composition and function of the RM.

The fire support system is essential in the battlespace. The fire support system requires an algorithm to support its optimized function as mentioned in [31]. The algorithm is used in the evaluation process of executing the firing mission. The critical features include the availability of the weaponry in question, its range, and its effect on a specific target and the status of the weaponry (i.e., in use/waiting for a fire support command). The example presented in Figure 11 depicts the processing of fire support order requests inside the RM as an informal Specification and Description Language (SDL) diagram. This action performed by the RM is essential to proceed in the process of offering requested service/s [33].

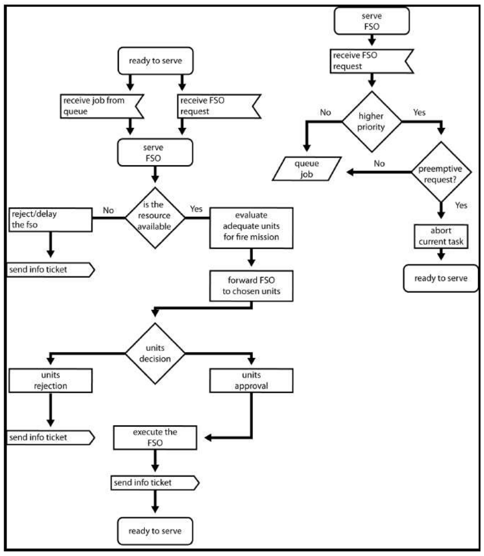

Figure 11. The processing of Fire Support Order requests in RM in an informal SDL diagram.

In a Fire Support Order the decision to execute the requested action, to fire, is made by a human being, an officer. In the future, when fire support decision algorithms are more fine-tuned, the decision to execute the mission can be forwarded to a Battle Management System. The BMS will then select the weapon and suitable ammunition for a specific fire mission. The BMS can also pre-evaluate the amount of ammunition type needed (how many shells it takes to destroy the target).

Each request comes with a time-stamp and own identification, contains route data and is traceable whenever tracking data are required. Each request is categorized according to an urgency class and its execution process is continuously monitored and evaluated. Once the request has been executed, it will be filed as a completed task in the common database. The tracking data of the completed request can be retrieved for analyzing purposes at any time by the system operator.

From the perspective of SOA and the Resource Manager, the described systems enable improved capability to align the listed and noticed services. When necessary services can be recognized and their state and phase have been identified, it may be possible to efficiently utilize own resources, for example, in a dismounted company attack. The process of a dismounted company attack was depicted earlier in Figure 2.

Operating in a military setting requires organizing matters related to command and control. It is mandatory to be able to sustain the composition of troops while soldiers get killed, wounded and missing in action. Dynamic hierarchy and performance value calculation were described earlier in Figure 7 and Figure 8. The orchestration of command chains and troops require reliable performance from SOA and the RM, but also a reliable means of communication and ubiquitous communication networks to support selected frequencies and used waveforms and bandwidths.

Although the requested services can be processed with the listed tools (Resource Manager and Scheduler) and outlined methods of organizing services (Business Process – like actions assisted with SOA), the system still remains incomplete because it lacks a key tool, a grid that takes into account all the relevant and constantly changing variables, such as the planned duration of an operation, the type of terrain where the operation is taking place, the expected troop performance and the capabilities of a specific military unit. None of the expected performance or capability values have been determined, evaluated or inserted as part of any Battle Management System.

VII. COMMUNICATION AND NETWORKS

The significance of functional communication systems and appropriately planned networks is substantial. To execute effective military operations as part of Network Centric Warfare, communication and network systems have to be carefully tailored in order to ensure that the services used can be located, identified and orchestrated together with SOA and with the assistance of the RM. Allocating and resourcing services becomes impossible without ubiquitous and secured network and communication systems.

The primary function of a communication system is to support Command and Control and support those actions. The main objectives of the systems involve providing Common Operational Picture of the battlespace in near-real time and sharing data among the battlespace systems. The systems utilized facilitate the fusion and display of intelligence information to commanders at all levels and handles the exchange of targeting data from sensor to weapon systems. This loop is called a loop from sensor-to-shooter-loop; the shorter the loop, the more effective the weapon system. Communication systems used have to support various waveforms, frequencies, transmission protocols, offer adequate bandwidth and Quality of Service (QoS). SOA can be seen as an organizing tool of systems utilized. Figure 12 explains the network system from sensor to shooter.

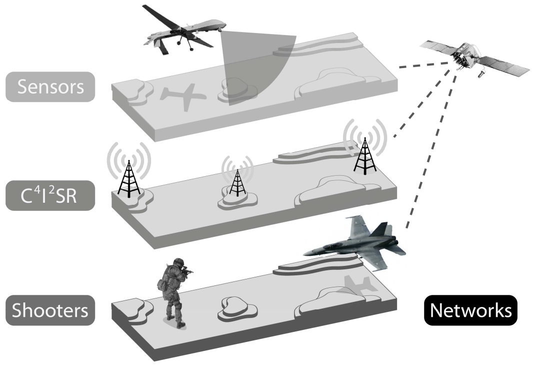

Figure 12. Network from sensor to shooter.

The speed and versatility of military operations keeps increasing unpredictably. Asymmetric and hybrid warfare set challenges for maintaining the ubiquitous networks in battlespace. If the Resource Manager does not identify the existing service, it can neither offer nor allocate it to any consumer (soldier).

The amount and versatility of collaboration tools also increases in the battlespace. Commanders' digital assistants of several types require constant and reliable connectivity to a functional network system with adequate bandwidth and the possibility to transmit data in different formats and also live footage from the battlespace. Different collaborating entities benefit from various tools and programs. Interfaces between military organizations can be challenging. A battalion commander and Company Commander use different tools for command and control. The used tools may rely on different frequencies and waveforms. The user challenges that surface are versatile when military units cooperate with civilian authorities or with Non-Governmental Organizations, when waveforms and tools may vary to a great extent. These challenges have been discussed in [35].

The concept of Network Centric Warfare has been created to support agile and versatile military operations in rapidly altering battlespace. To offer, allocate and trace services requires a comprehensive network system to ensure the ability to use these services. Without a ubiquitous and reliable communication network system, the execution of a successful military operation is endangered and likely to fail. In modern warfare communication services cannot be constantly produced by the performance of military satellites. Ubiquitous network systems require simple and local solutions in military operations executed in a low level (company and below).

Recent developments in modern military battlefield systems greatly influence today's military commanders and their performance. Modern devices such as smartphones are today supported by a complex infrastructure that enables high-speed communications and access to voice and data services anywhere, anytime. This is true only in theory. Constant communicating capability is hampered by latencies, disrupted connectivity in electromagnetic spectrum. Typical tactical operations benefit from the systems based on Local Area Communications (LAN). These systems are increasingly being employed to keep platoon and company level soldiers and assets connected with one another and their battle-group commander. Voice communications are being replaced with secure data connections as latest developments in the technology sphere indicate [2]. Moreover, communication systems based on Internet Protocol (IP) suite of products can be used to create a complete Wide Area System (WAS) with a number of Local Area Networks (LAN) in order to provide the required services for the consumer of a modern tactical communication network system. The maximum number of users in this type of network system is claimed to be 300 [2].

An example of typical soldier-worn personal radios are compact, cost effective and military graded transceivers that ensure secure and reliable voice and data communications for squad teams and higher echelons in many tactical scenarios, such as dismounted, vehicular, naval and amphibious operations. New radios are embedded with GPS/GLONASS receivers for automatic position reporting. Personal radios offer lightweight and low consumption transceivers operating in the frequency of 2.4 GHz Industrial, Scientific and Medical (ISM) band with a very low Radio Frequency (RF) signature modulation scheme based on spread spectrum technology (DSSS) and providing a robust, reliable and low probability of detection time division multiple access (TDMA) waveform. Radios typically feature advanced encryption standard (AES) encryption providing a very high security level on the transferred audio and data systems, while security keys can be downloadable. Personal tactical radios can provide several tactical communication services, such as full-duplex voice conferencing, GPS reporting, e-mail, chat, file transfer, as well as real-time video streaming [2]. On top of these systems, some of these can be seen as a wireless extension for an Intercom System and Combat Net Radios; they allow users to be connected to the vehicles and their main radio equipment via independent push-to-talk (PTT) selection. Software Defined Radios (SDRs) are on their way to tactical military environment. Typical SDRs' features include: Multiband 30 – 512 MHz, multimode, multi-mission, software programmable architecture, Low Probability of Detection (LPD) and Low Probability of Identification (LPI), simultaneous voice and data, near-real time data transfer for sensor to shooter applications and lastly integration to Strategic Communication Systems [2].

VIII. THE USE OF UNMANNED VEHICLES

The possibilities to benefit from Unmanned Vehicles (UVs) as relay-stations and sensor nodes deserve to be considered. Issues such as Low Probability of Detection and Low Probability of Identification have to be taken under close study and evaluation. When communication systems and services can produced with the assistance of UVs, they are easier to replace and the re-routing of the lost connection or connectivity can be arranged with a better probability compared to a satellite-based communication system of a higher echelon.

A typical UV can be a dispensable robot capable of overcoming the communications problems that soldiers encounter in built-up areas. Robots are usable in land and at sea, or air-borne, representing Unmanned Aerial Systems (UAS) or Unmanned Aerial Vehicles (UAVs) [36], [37]. Robots are utilized to reconfigure the prevailing communication infrastructure enabling the soldiers to stay connected with their lines of communication in versatile and altering urban communication battlespace. Throwable robots can act as an assisting tool in gathering data from the harsh and hostile battlespace [2]. It is crucial to understand the challenges posed by network connectivity constraints in the formation and reconfiguration of the network system in the environment, which UVs operate. The problem of formation control with network connectivity is discussed in [38].

SOA can serve as a tool in military operations in organizing and orchestrating networks and their topologies and in the process of re-routing the connection between users. Challenges related to Persistent Tactical Awareness (PTA) and Persistent Tactical Surveillance (PTS) [2] can be more easily solved if SOA and UVs can be utilized in gathering data and transmitting these data from the sensor to the shooter in an agile manner. Moreover, Command Posts create and update their Situational Awareness and Common Operational picture on the basis of the raw data produced by sensors embedded in the battlespace. Functional and reliable communication remains critical in Network Centric Warfare.

And lastly, communication networks have to be pre-planned to support sensor-throwable and sensor-shootable elements in different types of sensors. An example of the latter ones is described in [38]. Figure 13 depicts the functions of the Sensor Element Munition divided in different phases. When the data can be gathered beyond the horizon discreetly, the possibility of a success of own dismounted company attack is increasing.

The data collected with the assistance of Sensor Element Munitions can be used as real-time data to be inserted in the decision making process after the significance and reliability of these data have been evaluated and verified.

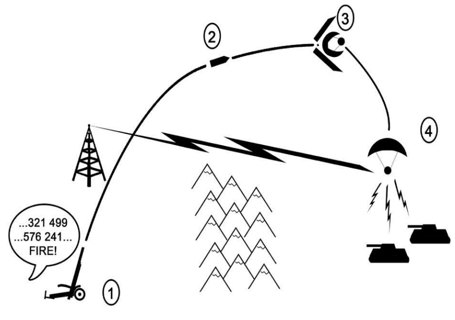

Figure 13. The usage of Sensor Element Munition.

IX. Grid for Interface Assisted Decision Making (GIADM)

As noted, neither the expected performance values nor the capability values of any military units have so far been calculated, assessed or inserted in any Battle Management System. The following discusses a preliminary idea concerning how to account for expected troop performance as a determined value together with time and terrain. The sketched Grid for Interface Assisted Decision Making (GIADM) exploits the data offered by means of SOA, the RM, and BP, and does so by using only one solution, which maximally exploits the results of all the systems. This type of an assisting tool needs to be algorithm-based because of the infinite number of affecting variables in a given military setting. For end-user purposes, the tool needs to be screen- or GUI-embedded, depending on the level of operation and that of a given military commander in an organization.

The proposed tool, a GIADM, aims at facilitating the decision making process of a military commander and can be benefitted in all types of military operations (defensive, offensive, special and Military Operations Other Than War), and is calculated on the basis of gathered data to support an existing military operation during its early planning stage. As an assisting tool, IADM serves the planning phase of an operation at all the army levels and draws on critical information based on the gathered knowledge on both own forces and the adversary, its actions and strength. Critical information includes time, distances between objects and troops, weapons available and the variety and amount of different types of supplies. In addition, features related to the prevailing weather, type of troops used, number and type of vehicles, type and nature of terrain and the capability of troops to execute a commanded mission are identified and quantified to determine the possibilities to execute a commanded mission. The levels of varying set objectives or actions can be marked on GIADM as depicted in Figure 14. To utilize GIADM, Graphic User Interfaces have to support its use. GUIs and their performance capabilities are discussed in Section X.

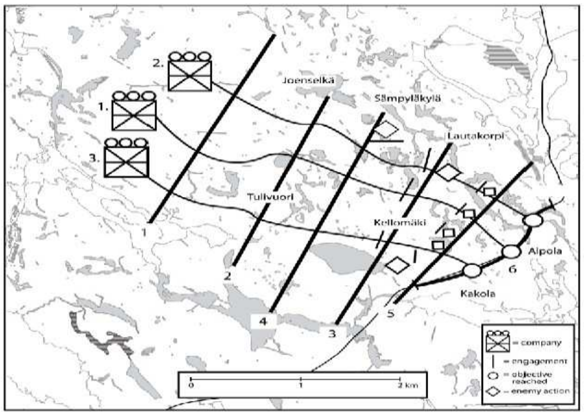

Figure 14. Set objectives marked on Grid for Interface Assisted Decision Making (GIADM).

When SOA is utilized to calculate the relative strength between military entities, the resources at hand may be optimized. This optimization means timing the usage of own resources, the amount of military force (troops, weapons, transportation, evacuation) available and its placement. When utilizing SOA and the Resource Manager in the planning process of organizing a military operation, the probability of a successful operation of a military maneuver may increase. This means saving own troops, fuel, ammunition, transportation vehicles and medical supplies.

These resources can be seen as services in SOA, the Resource Manager, and a resource or service in a Business Process. When all the parameters of the attack terrain, relative strengths of the entities (own, opposite force), amount of troops, different types of capabilities in performing operations are set in GIADM as variables, GIADM displays the results as suggestions on how to perform the commanded operation, as depicted in Figure 15, which visualizes only the pace of an operation from the perspective of a single soldier. Moreover, the use of friendly artillery fire can be presented in Graphic User Interface as a factor a single soldier has to take into account when performing a commanded task. This feature of the GIADM may aid in attempting to minimize instances of fratricide.

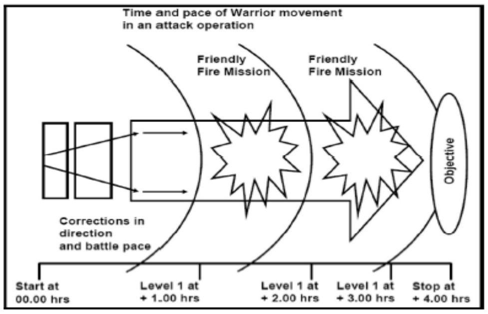

Figure 15. Suggestion of an operation, as visualized in GIADM.

X. GRAPHIC USER INTERFACE

Graphic User Interfaces are vital visualization platforms in the digitized military battlespace, in which military operations are executed speedily in constantly changing situations. Graphic User Interfaces can be identified as organic tools in command and control systems in contemporary warfare at all the levels of command and control systems; the higher the level in an organization, the more sophisticated the GUI.

The utilization of SOA in Network Centric Environments requires that the usability of Graphic User Interfaces be taken into consideration. GUIs have to be simple tools that assist the execution of a commanded military operation as visualization platforms of Battle Management Systems. When everything functions as planned, BMS can be seen as a system used to combine all the sensors, entities and devices to be used by higher echelon. BMS enables C2 processes executed in the battlespace. BML can be used in the interaction between Command and Control systems and as tools for course of action planning and analysis. When BPs can be embedded together with the assistance of an appropriate Scheduler, a Graphic User Interface of a Future Force Warrior may look as depicted in Figure 16.

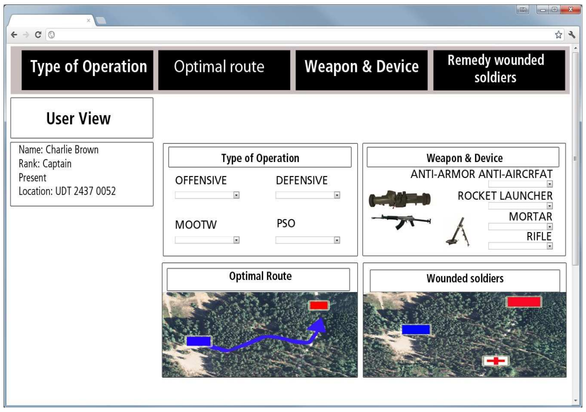

Figure 16. A view displayed by a Graphic User Interface.

GUI can serve both as a display and end-user device of a GIADM, especially at the lower command levels (company and below).

XI. SECURITY AND SCHEDULER

To account for operational security, there are protocols to identify the credentials of the requester entity by applying a security, authentication and agreement tool embedded in the RM. Before any tasks are ordered to be executed or resources allocated for use, the task or resource request is processed via the described system, as presented in Figure 17. An incoming task passes through a preliminary phase, in which it is checked and identified. Once the task has been verified and approved and transmitted from a trusted and secure cooperation entity, it will be processed via a series of approval and authorization policies.

Security issues remain critical also when dealing with unmanned aerial vehicles utilized in Network Centric Warfare at tactical level as described in [30]. The collected data have to be secured to remain intact and coherent when passing through different interfaces from the sensor to the shooter.

The described process ends with a phase in which the common language and tools are selected and then the given request moves forwards inside the RM. The overall description of the whole concept consists of three major parts and functions: 1) SA comprehending the existing solutions and tools, 2) command and control tools, and 3) information repository. These three together enable the command and control process and saving of logdata for further analyses. These functions presuppose the RM and the Scheduler to share and distribute the tasks and resources.

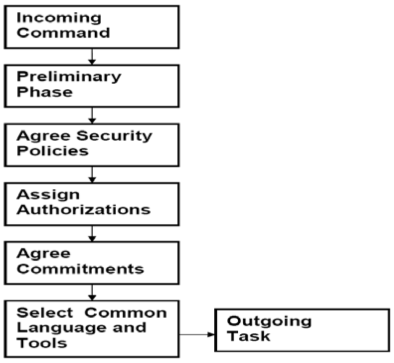

Figure 17. Security, authentiction and agreement system.

To provide the requested service, the RM requires one more component [34]. This critical component for the military use of SOA, which relies on the utilization of the RM is called the Scheduler. The role of the Scheduler is to coordinate processes to maximize the performance of resources and to reduce fratricide and collateral damage. The Scheduler enables militaries to execute various operations simultaneously but still under a strict command and control. The issue of simultaneously operations is solved by the element named Battlefield Secure Scheduler (BSS). This component uses two different methods of sharing calendar, Pre-Shared Scheduler (PSS) and Dynamic Schedule Update (DSU). The Scheduler functions together with the RM and utilizes SOA as a process. These elements can be recognized in Figure 18, which introduces the process from an incoming command/task to an outgoing command/task.

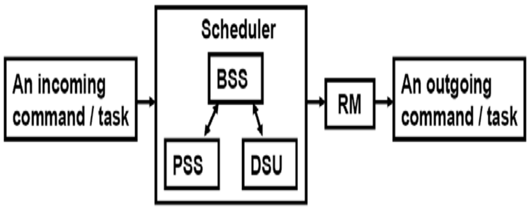

Figure 18. The elements inside the scheduler and the permeable command and control -process.

XII. BENEFITS AND DRAWBACKS

The delicate system introduced, the sketched Grid for Interface Assisted Decision Making exploits the data offered by means of SOA, the RM, and BP, but it does this by using only one solution, which exploits the results of all the systems. This means that the system can malfunction for various reasons. Challenges related to sustained energy supply have to be solved to enable the function of different processes. The orchestration of the system can also fail because of intentional enemy action (jamming, a virus, a worm). The system needs to be equipped with an analyzing program, which indicates when the system functions properly. If the system malfunctions and retrieving the capabilities becomes impossible, the system becomes useless for an FFW. This asks for an easily replaceable and fault-tolerant system with inbuilt check-in routines. Otherwise, traditional methods in orchestrating services need to be adopted.

By adopting SOA and embedding business processes into the existing command and control -system, the overall performance of military operations may be improved. With the assistance of the RM, limited military resources may be allocated more efficiently to the users requiring for services. When the Scheduler is implemented together with the RM into the BPs, it may be possible to increase the speed of decision making process together with the execution capability. The allocated resources available may then be used optimally. This means shorter execution times, and an increased amount of data for improved decision making. The overall system performance may be optimized with the assistance of these tools.

Offering a service of ubiquitous computing to battlespace commanders increases the possibility to utilize the resources available. This may foster a rapid decision making process especially when SOA can be embedded in the decision-making systems. As described in [22], SOA must deliver a solution that crosses existing boundaries as well as addresses the issues of information sharing regardless of where that information is stored.

By adopting these introduced elements into BMS together with SOA, it may be possible to gain improved capability to execute operations. This may also mean reduction in time needed for allocating resources and result in improved overall performance with minimized operations' execution times. Besides, with the improved level of SA, fratricide and collateral damage may possibly be reduced.

The system presented here is free to be adopted and tested. To create a functioning, automated business process applicable for future battlespace purposes requires development and testing, which accounts for matters related to adequate bandwidth, transmission power, connectivity, and operational security.

XIII. CONCLUSIONS

The introduced tool, GIADM, represents a follow-up idea-phase development stage in the quest for a comprehensive assisting decision making tool. GIADM combines gathered information from the existing resources and platforms connected to the Battle Management System. GIADM functions on top of BMS, SOA, RM and other possible tools for assisting in the decision making process and location of troops.

Synchronizing a sustainable performance of military troops, achieving the set objectives, optimizing the use of unmanned vehicles and timing of operations remain necessary. These in turn affect planning the resources to be orchestrated and allocated to minimize casualties and ensure short recovery times.

A commander has to be able to use an optimum amount of force. Because of the inevitable casualties, troops must be reorganized periodically in an unpredicted manner. SOA can be benefitted in the action of reorganizing the composition of troops and their resources. Resource Manager is integrated into SOA and Business Processes in order to assist the commander to target the reinforcement of troops and services to the area of operation in which they are mostly needed. The functions of Resource Manager take the use of Unmanned Vehicles into consideration. The data collected by robotic vehicles in inserted in the command and control system via Battle Management Systems of various types.

The data collected are then inserted in the tool labeled Grid for Interface Assisted Decision Making. After the analysis, a commander receives a suggestion how to execute an operation in relation to time, troops, terrain and the type of an operation with the objective to minimize the needed amount of supplies and services and thus save resources for the follow-up action.

The timely reorganizing of troops requires that the data collected have to be presented in an appropriate manner depending on the level of a military troop commander (platoon leader, company commander, battalion commander). Simple to use, affordable Graphic User Interfaces are in essential role in low level operations.

Militaries adopt digital systems created for assisting the process of decision making and operational planning. These systems continue to need further development in order to be fully adopted in operational use. When militaries continue to aim at optimized performance with the assistance of Service Oriented Architecture, the systems embedded in SOA and Business Processes have to be properly organized and orchestrated. The amount of interference between different systems has to be minimized with careful planning sequences already when systems are being designed and built. This ensures that the relevant data remain intact and uncorrupted. Unfortunately, neither the technical readiness level of these systems nor the capability to link these systems together is currently at an implementation level. Some of the challenges have been identified in this paper to contribute to the process of embedding digitalized automated systems in the battlespace.

XIV. Further Work

When the process of war has been modeled to resemble a Business Process, the performance of Future Force Warriors may be optimized with the assistance of processes assisted with SOA. The result of this may be seen as an agile and modular military performer with improved capabilities and improved Situational Awareness, and the capability to utilize ever diminishing resources more optimally with decreased instances of fratricide.

Further work related to modeling a war as a Service Oriented Architecture assisted business process must concentrate on the orchestration of systems. Challenges posed by operational security cannot be neglected, as they continue to disrupt digitized battlespace. Issues related to sustaining an adequate level of constant energy flow and protection against violations caused by electronic warfare must be studied, tested and solved before adopting GIADM in operative use.

Both extensive funding and considerable human resources are required to run the extensive number of validity tests necessary, which would result in getting all the systems up (i.e., BP, RM, Scheduler) running synchronized with GIADM. Firstly, tens of thousands of simulation laps involving each operational scenario type, including defensive, offensive, and Special Operations, are required before implementing the introduced system/prototype into any real-time military exercise performed. Secondly, once any resources have been allocated for and invested in implementing a GIADM type of approach to complete a functional command and control tool that assists in decision making, the system design can no longer be accessed in any public domain data sources.

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