Optimizing the Performance of a Dismounted Future Force Warrior by Means of Improved Situational Awareness

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***Abstract*—The future operational settings involve a battlespace where warriors and commanders rely on SA-tools to perform optimally in their given tasks. This may include combat settings in Military Environment (ME) as well as counter insurgency actions, peace-keeping operations and operations in Crises Management Environment (CME). In multi-national operations taking place in versatile and hostile environments, it is essential to detect, classify and identify the encountered objects and targets in the battlespace early enough. Consequently, the concept of war has changed in the direction of multi-symmetric warfare involving enemy troops, own forces and impartial entities. This paper discusses the existing and applicable Commercial-off-the-shelf (COTS)-based communication technologies with solutions suitable for military operations. These examples are examined by focusing on enhanced Situational Awareness (SA) as a tool facilitating improved decision making processes to support the execution of operations in a versatile battlespace and thereby optimize the performance of a dismounted Future Force Warrior (FFW).**

Keywords-Situational Awareness (SA), Common Operational Picture (COP), Wireless Polling Sensor Network (WPSN), Performance, Future Force Warrior (FFW).

I. INTRODUCTION AND DEFINITIONS

The purpose of this paper is to examine the existing and applicable Commercial-off-the-shelf (COTS) based communication tools available for enhancing dismounted Future Force Warriors' Situational Awareness (SA) and thereby maximizing their performance via improved decision-making capabilities. Dismounted warrior fights on foot, not inside of a vehicle. This paper begins by introducing the topic and key terminology followed by covering related studies [1]. Then the text turns to challenges concerning Combat Identification (CID). Then a comprehensive approach to targeting process is discussed. After this, the paper examines the means of accruing data for improved decision making processes and moves on to challenges involved in distributing Situational Awareness-data. Then the focus shifts to location and communication possibilities in urban areas followed by the discussion section and the conclusions.

When optimizing the performance of Future Force Warriors (FFWs), the data distributing and processing capabilities become seminal in enhancing improved SA and data distribution to enable near real-time Common Operational Picture (COP) and Shared Situational Awareness (SSA). Once the location data of varying entities can be reliably forwarded to respective command posts, the number of fratricide incidents and collateral damage can be significantly minimized.

Once identifying and defining relevant information and its distribution in the battlespace is determined as the key in Network Centric Operations (NCO), every effort to ensure the information flow between own warriors and sensors needs to be analyzed [2]. Contemporary weapon systems require greater amounts of intelligence data at a higher fidelity than ever before [3]. Since operations tend to be multi-national, different sensors and systems are required to communicate understandably between each entity to minimize fratricide and collateral damage by maximizing the distribution of the near real-time COP. One solution involves utilizing Business Management Language (BML) [2].

This paper concentrates on tackling the following three questions: 1) How to optimize the performance of a dismounted FFW by means of improved SA? 2) How to increase SA with the available COTS-based communication technologies? 3) What are the means to avoid casualties, collateral damage, and fratricide?

As for key terminology, a new network structure called the Wireless Polling Sensor Network (WPSN) is explained in [4]. Since nodes do not form a network per se but rather are polled by a selected node of the mobile network, they remain undetected due to their passive nature. The network structure offers a new and ubiquitous way to share and forward all kinds of data, including data collected by various sensors. Moreover, the outdated Identification Friend or Foe (IFF) systems are replaced and supplemented with effective and accurate means to identify the prevailing objects.

Examining the means to minimize fratricide and collateral damage presupposes applying the model presented in Figure 1. This terminologically updated model emphasizes how Tactics Techniques and Procedures (TTP), Combat Identification (CID), Common Operational Picture (COP), and Situational Awareness (SA) play a central role in minimizing the number of fratricide incidents and collateral damage.

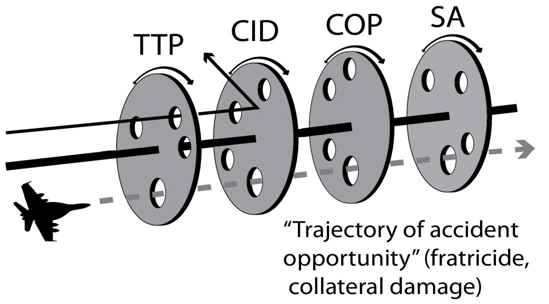

Figure 1. The Reason's Swiss Cheese Model updated by applicable terminology as a tool to explain the mechanism of avoiding fratricide and collateral damage, Blue-on-Blue (BoB) [5].

An applicable definition for Situational Awareness (SA) is given in the Army Field Manual 1-02 (September 2004): "Knowledge and understanding of the current situation which promotes timely, relevant and accurate assessment of friendly, competitive and other operations within the battlespace in order to facilitate decision making. An informational perspective and skill that fosters an ability to determine quickly the context and relevance of events that is unfolding."

The process of determining the affiliation of detected objects in the battlespace equals Target Identification (TI) [6]. When using this categorization, blue denotes the friendly force, red the enemy, and white refers to neutral (impartial) entities. The traditional method of TI is based on visual signature of the object of interest. In contemporary warfare TI is also based on utilizing the electromagnetic spectrum of the target. Properly applied, data and sensor fusion can be seen as a means to prevent collateral damage and fratricide. As a matter of fact, TI can be divided into two categories: Cooperative Target Identification (CTI) and Non-Cooperative Target Identification (NCTI). CTI allows a human shooter or sensor to interrogate a potential target and thereby forces the potential target to respond to the interrogation in a timely manner as described in Figure 2 [5] [6].

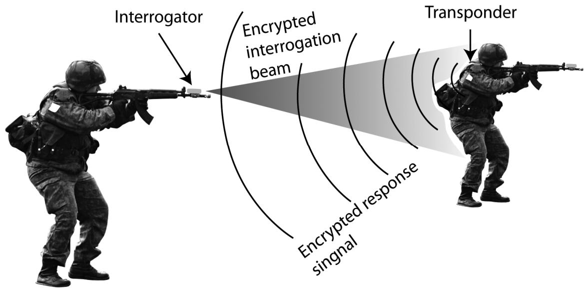

Figure 2. The process of Cooperative Target Identification (CTI) [5].

In contrast, NCTI does not require a cooperative response from the target. NCTI involves systems or methods which exploit the physical characteristics of entities in the battlespace to help identify and determine affiliation. NCTI systems include optics, such as Thermal Weapon Sights (TWS), night Vision Goggles (NVG), Forward Looking Infrared Radar (FLIR), as well as vehicle and personnel markings, for instance, Joint Combat Identification Marking Systems (JCIMS) [6].

Combat Identification can be defined as a process of attaining an accurate and timely characterization of detected objects in the joint battlespace to the extent that high confidence, timely application of military options and weapons resources can occur [6][8]. An extension of this can be understood as a process of accurately characterizing the detected objects via the operational environment sufficiently to support engagement decisions [6]. The purpose of CID is to enhance unit combat effectiveness and simultaneously minimizing fratricide. In the form of an equation CID reads as: SA + TI = CID [6].

The core capability in SA is Common Operational Picture that fosters effective decision making, rapid staff actions, and appropriate mission execution [6][9]. COP is employed to collect, share and display multi-dimensional information to facilitate collaborative planning and response to security incidents. COP typically comprises three types of modules as indicated in [5]: 1) information gathering sources that observe events and report information to the command and control module, 2) a command and control module that makes decisions based on both information received directly from its information gathering sources and information reported by other peers, and 3) display units at the emergency location that receive instructions from the command and control module [6].

The acronym MOUT (Military Operations on Urban Territory) denotes military actions planned and conducted on a terrain complex where manmade constructions impact the tactical options available to commanders. Urban combat operations may be conducted in order to capitalize on the strategic or tactical advantages gained by the possession or control of a particular urban area or to deny these advantages from the enemy [4]. The characteristics of MOUT include complex situations brought about by engagements in urban environments (ambushes, civilians).

Combat Effectiveness (CE) can be defined as the ability of a (friendly) unit to rapidly and accurately sort and categorize detected objects (blue, white, red) and make a decision as to whether or not to employ deadly force against the identified object/target. Effectively applying the CE guarantees a minimum level of collateral damage and fratricide.

Now, to exemplify the previously defined terms, the following briefly examines Rules of Engagement (ROE). Together with tactics, techniques and procedures, ROE defines guidelines which then support an individual in a situation when a decision is made about whether or not to open fire. TTP supports the decision making process regarding force implementation in the Area of Operations (AOR). Depending on the ROE formulations, the orders concerning using force may vary as indicated in Figure 3.

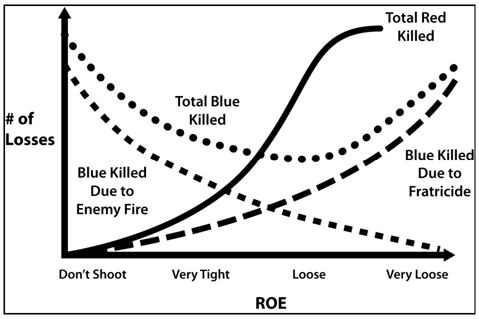

Figure 3. ROE in relation to the number of troops killed (blue, white, red) and the number of losses and fratricide [5].

All warriors depend on situational awareness (SA) [10] which can be provided also by using WPSN-systems introduced in [4]. The Blue Force Tracking-systems (BFT) along with the White Force Tracking (WFT) presented in [5] provide vital information for improving commanders' decision-making and avoiding fratricide and collateral damage. Blue Force (BF), allies and White Force (WF) need to be constantly precisely located.

II. RELATED WORK

This study has a strong linkage to dismounted FFW programs and Soldier Modernization Programmes (SMPs) ongoing in all major militaries. Obviously, they continue to be increasingly significant in enhancing the overall performance of militaries regardless of the financial retrenchment and downsizing demands. These programs concentrate on improving and updating dismounted soldiers' equipment thereby optimizing performance to minimize collateral damage and fratricide. The specifics related to the challenges concerning gathering and forwarding information are well known by militaries around the world. However, since nations invest significant sums of money on development projects, the specifics tend to remain classified and no valid test-data are available. The same applies to mathematical formulae, simulation results, and other types of ad hoc testing reports. Thus comparing and analyzing existing Future Force Warrior communication systems and architectures is currently a research mission impossible as the data remain unavailable for validation purposes. Developing military gear for future armed forces, and special operation forces in particular, continues to be expensive as devices are necessarily tailored for a limited number of users. This is why COTS-based gear solutions become an attempting alternative for military purposes as well.

Moreover, the existing COTS-based Command, Control, Communications, Computers, Intelligence, Information, Surveillance and Reconnaissance (C4I2SR) technologies with their applications are relevant in facilitating the developments necessary for overcoming the varying challenges encountered in the future battlespace.

In terms of practical battle proof examples, the technology for Blue Force Tracking (BFT) was used during Operation Iraqi Freedom (OIF) for coordinating operations among the Joint Services and with allies and resulted in reduced causalities due to enhanced SA [11]. Understandably, the means to increase SA via improved BFT and WFT are also developments in progress. Figure 4 illustrates an example of the dismounted FFW system from the perspective of selected warrior gear.

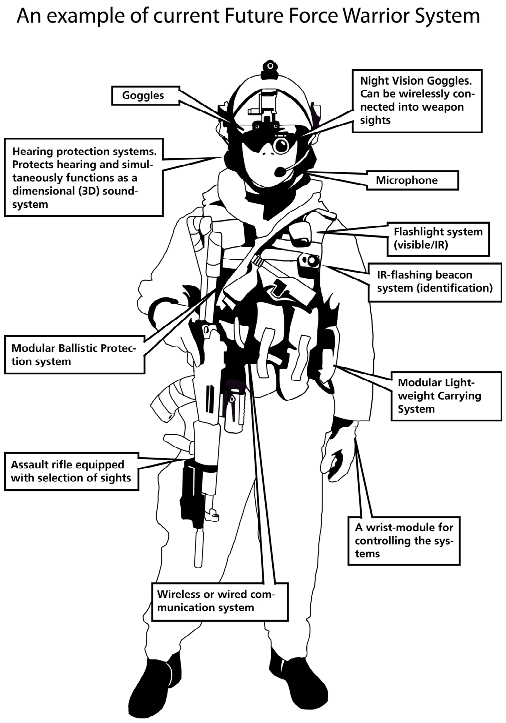

Figure 4. An example of a dismounted FFW with selected gear.

As introduced in [12], this paper continues to examine the interconnectedness of trained FFW and their gear in the light of the following three warrior levels: 1) the basic Warrior at the bottom level, 2) the Readiness Brigade Warrior, and 3) the Special Forces Warrior. The amount of TID and SA data varies along with the level of a FFW. In the higher echelons, the amount of data gathered via sensors and tracking systems is vast. To transmit and distribute the location information filtered and fused through various systems remains a challenge. A basic warrior located on the ground must fight rather than monitor his palm or wrist computer or lap-top.

In the building process of FFW, the key element is the hierarchy of the warrior levels (Basic, Readiness Brigade and Special Forces Warrior). As described in [12], concerning warrior levels, FFW act as moving relay stations to ensure the throughput of communication devices used. A warrior is in a key role in low level operations, and a warrior acts as a node or sensor in Network Centric Operations [12]. The FFW is an applicable sensor platform for Netcentric Operations as indicated in Figure 5.

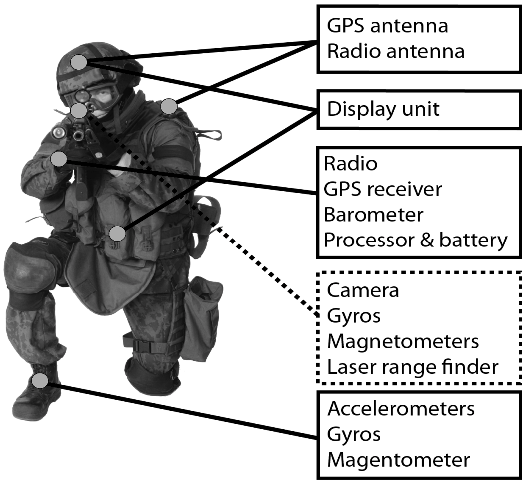

Figure 5. An example of a fully integrated Warrior for location purposes outdoors, indoors and in MOUT for contemporary warfare [19].

The principal contributing efforts, technical and procedural, involve the following [10][11]. First, CTI, automated query or response systems for dismounted personnel and light vehicles need to be addressed. Secondly, a means to share SA systems for employment at the platoon, squad, team, and individual levels must be applied. Thirdly, digitally-aided supporting fires' coordination and control must be defined. Fourth, Digitally-aided Close Air Support (DCAS) coordination and control has to be applied. In addition, challenges with Combat Identification Server (CIS) interoperability and Personnel Recovery Command and Control need to be solved. Lastly, marking and beacon systems for dismounted personnel, light vehicles, and friendly locations need to be applied. In fact, the US Army is fielding its new SA system known as Force XXI Battle Command and Brigade and Below (FBCB2) [10][12]. One of the keys into the success is careful mission analysis and thorough evaluation of Courses of Actions (COAs). Both processes can save time and minimize collateral damage. The use of available Blue and friendly Forces and resources can be optimized. This increases efficiency and along with minimum casualties, leads to minimum recovery times.

III. CHALLENGES IN COMBAT IDENTIFICATION

In military operations everything is done to prevent fratricide. Currently, identifying a warrior regardless of the visibility conditions is essential. As evident in Figure 2 earlier, both an interrogation unit and a responder unit are necessary, presupposing, first of all, that the systems are fully operational, and, secondly, that the distance between the warriors is appropriate. In case the identification system doesn't reply, a human is making the decision to open fire based on the TTP. The Identification to whether or not to open fire is based on the visual signature of the uniform, weapon and gear [5].

However, one needs to keep in mind that there is always the possibility that the location device gets stolen or misused by a third party in that, for example, an insurgent tries to function as a member of the White Force [5]. In order to increase the reliability of the system, the tracking devices have to be pre-coded and tied in pairs in advance before entering the battlespace to prevent the stealing of the tracking device. Once paired devices are torn apart, they stop functioning as planned – and devices become dysfunctional [5]. After the separation process, the devices must be re-paired and re-coded by the operator. During this process, the operator re-identifies the person.

IV. COMPREHENSIVE TARGETING PROCESS

First of all we start with the Point of Interest (POI) in the battlespace. When the POI has been detected, classified and finally identified, it may be indicated as a potential target. POI is not automatically a target. The utilization of Unmanned Vehicles (UVs) and Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) play an important role in target acquisition, starting from the phase of detection of a POI.

When returning to ROE/TTP (whether or not to open fire), a link behind the targeting process deserves a closer look. The process is known as Detect, Identify, Decide, Engage, and Assess (DIDEA) [6]. The DIDEA provides an iterative, standardised and systematic approach supporting targeting and decision making, being generic enough to be used as a systematic process for Command and Control (C2) node targeting and decision making. Separate actions inside DIDEA area as follows [5]:

Detect: The process of acquiring and locating an object in the battlespace by analysing the phenomena in the electromagnetic spectrum.

Identify: The process of classifying an object into the category of blue, white (neutral) or enemy. This represents a primary step where specified CID tasks are accomplished.

Decide: The decision making process that follows the detection and identification phases. This is the most generic step within the process and represents the primary step where a specific ROE application occurs. In the decision-making phase, the executive officer / warrior has to decide and define what type of weaponry is appropriate for to the mission. In cases of opting for the use of deadly force, the following questions need to be addressed: 1. Can I engage (ROE application)? 2. If there are several targets, what is the order to engage the selected targets? 3. Which one is the most appropriate weapon system (most cost-effective, appropriate against the selected target)?

Engage: The execution of selected weapons in a selected order starting from the most dangerous target moving on according the panned sequence.

Assess: Monitoring the gained effects with the use of destruction power. Employing the force of various weapon systems available is repeatedly executed until the required level of destruction is achieved.

Once the critical data have been collected they have to be quickly analyzed to be used for evaluating different Courses of Actions. Success depends on an accurate mission analysis and a timely evaluation process of the accrued data. Improved SA results in optimal time for mission execution and simultaneous minimizing of casualties, which increases efficiency and leads to minimum recovery times improving the overall efficiency of the troops utilized.

Once commanders have access to more current reconnaissance data for mission execution, they are able to analyze different COAs and, calculate the pros and cons to evaluate the best possible method to operate in any scenario prevailing. As explained in Figure 6, military commanders have by default value at least two different options for executing the mission in question. Once the Military Decision Making Process (MDMP) has been completed, the most effective operation can be executed to maximize the performance of the designated troops. In the described scenario below, the commander focuses the performance on destroying the Command Post (CP), the alternative number 2, instead of attacking against the armored enemy.

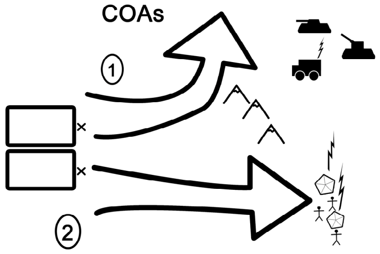

Figure 6. Possibilities of COAs [13].

When it comes to SSA, it is crucial to be able to distribute the accrued data rapidly and accurately in order to ensure success in military operations. When the accrued data remain intact and non-corrupted, both the execution of operations and the evaluation of COAs at all commander levels are improved. In particular in joint operations, the effective distribution of COAs and SSAs is in a central role.

V. HOW TO ACCRUE DATA FOR THE DECISION MAKING PROCESS?

Self-evidently, cases of fratricide and collateral damage are bound to surface to some extent. Militaries are interested in locating both own troops and also increasingly the neutral entities of Non-Governmental Organizations (NGOs) and Governmental Organizations (GOs), the WF, the members of which can be tracked by using WFT described in [1].

Briefly put, the problem relies in relating the TTP, CID, COP and SA to the rules of ROE. This involves dealing with the balance described in Figure 3 earlier. If ROE formulations are too strict, for example, the commander's intent is to avoid the use of deadly force unless it is absolutely certain that the targeted object is positively identified to be an enemy – the Blue Force will suffer on the basis of the actions caused by the enemy. And, if ROE formulations leave too much room for interpretation, various types of casualties (red, blue and white) are bound to occur. Thereby the transmission of combat-critical location and identification data plays a crucial role in the battlespace.

The process of a complete targeting process can be described in a simplified form in a formula: Detect, Identify, Decide; Engage and Assess [6]. The DIDEA provides an iterative, standardised and systematic approach supporting targeting and decision making, being generic enough to be used as a systematic process for C2 node targeting and decision making. This process is thoroughly discussed in [6].

Furthermore, older existing systems are available for distributing data gathered by various types of sensors in various types of military and humanitarian crises environments. These technologies are based on WPSNs described in [4] and Wireless Sensor Networks (WSNs) described in [14][15]. The former are passive and will remain hidden whereas the latter are active and represent a more easily detectable system. Both systems are applicable in transmitting constantly flowing data from a sensor to a node, for example, to a vehicle or an unmanned vehicle (UV).

As suggested in [12], viable COTS-based methods exist, which improve the C4I2SR of a warrior at all the levels. The examples covered are based on usability cases of WPSN-solutions. They indicate that a warrior can obtain more critical information on the battlespace by using the presented WPSN solutions. This improves the general efficiency of a warrior at all levels. The platforms used today on the battlespace are not efficient. This is because they are based on a single sensor and they do not collect data in a way that would allow collaboration of multiple sensors. The proposed solution makes use of multi-sensor collaboration for improved location information and improved SA. Figure 7 explains the structure of a warrior skeleton as well as the location of the WPSN-system inside the FFW-system [4].

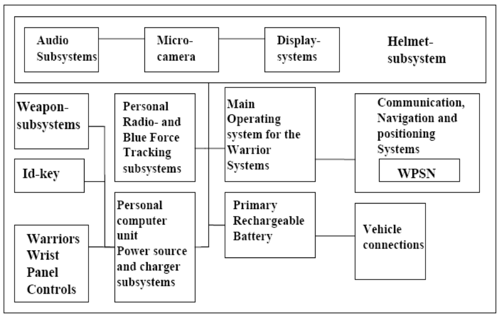

Figure 7. A Warrior's electronic skeleton [4].

In terms of FFW equipment, warriors need to be functional and their gear must be planned according to the set tasks. A key factor is the efficiency of a warrior, which can be gained via an improved SA, BFT and Command and Control. Warriors have to maintain their agility and remain active in the battlespace. However, since only combat-crucial gear can be hauled along, thereby not nearly all the gear necessary can be attached to the dismounted FFW. Thus the warrior skeleton and its communication systems need to be carefully defined and built at each warrior level according to the given task requirements. Currently, the present solutions seen in active use are cumbersome and lack integration. The WPSN-solutions still remain unapplied in these platforms. Thus the maximum potential remains unreachable without effective sensor and data fusion. Militaries are moving towards smaller specialized units while the overall performance requirements keep increasing. At the same time troops are designed and trained for dismounted operations in which a greater degree of flexibility and reliability of battle-proof and robust systems are needed.

Practically speaking, small militaries are often unable to utilize the possibilities in target acquisition offered by UVs and UGVs. As introduced in [13], affordable and easily deployable Sensor Munition Element (SEM) offers new possibilities to accrue data behind the enemy lines. The system is based on Commercial-off-the-shelf (COTS)-products and is affordable for the use of small troops utilized in small militaries.

Means to accrue SA-data in the battlespace are depicted in Figures 8 and 9. All available means are utilized in order to avoid fratricide and collateral damage thus maximizing the performance of own troops to ensure mission success.

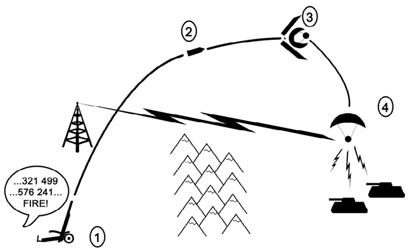

Figure 8. On deploying an SE above an enemy territory: 1) Fire Support Order is commanded, 2) SEM is airborne, 3) SEM opens and ejects the SE, 4) the SE starts to transmit gathered data from the enemy territory and targets [13].

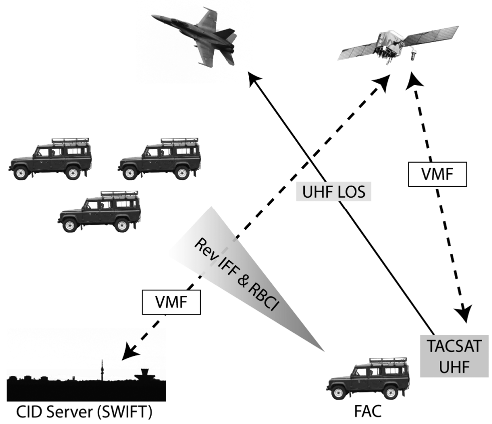

Figure 9. The Comprehensive system of gaining SA-data to avoid collateral damage and fratricide [5].

The decision as to whether or not to open fire is based on the visual signature of a given uniform, weapon and gear as well as magnetic, seismic or acoustic signals identified by a sensor [14] as described earlier. Self-evidently, the transmission of combat-critical location and identification data play a crucial role in the battlespace. Once the accrued data have been transmitted and received, they flow through a dissemination process, where these data are analyzed and fused to form a COP and to increase the overall SA. Figure 10 explains the process of Signature Prediction Process (SPP).

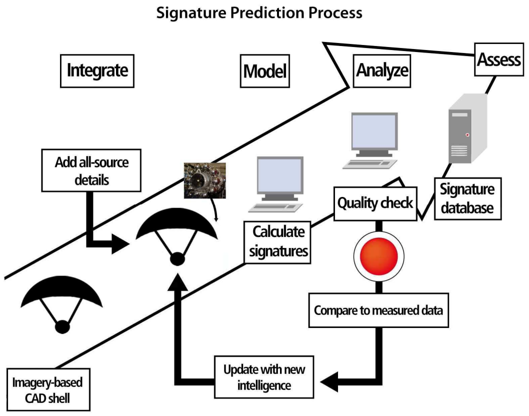

Figure 10. The Signature Prediction Process, typical of several available surveillance and detection systems.

The destruction power of a given weapon system has to be optimized according to the enemy location (forest, open area, Urban Territory), the state of movement on-the Move (OTM) or at-the-halt (ATH), and the protection-level (mounted, dismounted, dug). Apart from this, the commanding officer must keep in mind that operations are executed with improper SA, COP and suffer from lack of precise real- time CID.

Figure 11 emphasizes the importance of SA around the target area. The shooter has to be aware of the locations and status of both own troops and the enemy. It is critical to optimize the destruction power of a weapon system along the identification of a target. When the target represents a hierarchically critical enemy commander, he or she can be destroyed by transmitting the coordinates and visual signature to the designated shooter, as indicated in Figure 11.

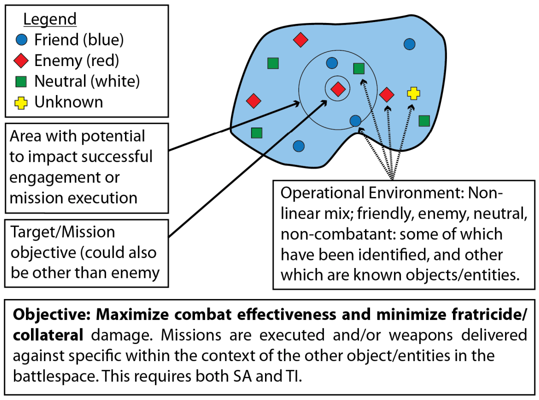

Figure 11. The importance of the SA around the target area [5].

To enhance improved SA and COP, Geographical Based Situational Awareness (GBSA) can be utilized [14]. The system utilizes the VHF-frequency operated Combat Net Radios (CNRs). When the CNRs are on the connectivity range, they recognize and identify radios in the system. Once the radios are at the same channel and the clock (hopping sequence) of CNRs are in a correct time, a reliable SA-tool

[14]. The main problems related to this system have to do with the clock and hopping sequence. This is one possibility to minimize fratricide and collateral damage. At the moment, the main benefit of this concept is in preventing from being fired at by own weapon systems, minimizing incidents of fratricide by means of improved SA-information.

VI. Challenges Involved in Distributing Situational Awareness Data

The amount of data accrued via versatile sensors and tracking systems is necessarily immense to say the least. As a result, to distribute the location information filtered and fused through various systems remains a challenge. As said, warriors' main function remains to fight instead of double-checking monitor his palm-top or equivalent. Besides, there will always be disturbances in electromagnetic spectrum, quality of service (QoS) and transmitting power along with the limited bandwidth set limitations to the ubiquitous communication systems. As indicated in Figure 12, the possibilities of battlespace communication are versatile, since almost all the sensors utilized are somehow linked together to facilitate BFT and CID and to improve COP and SA.

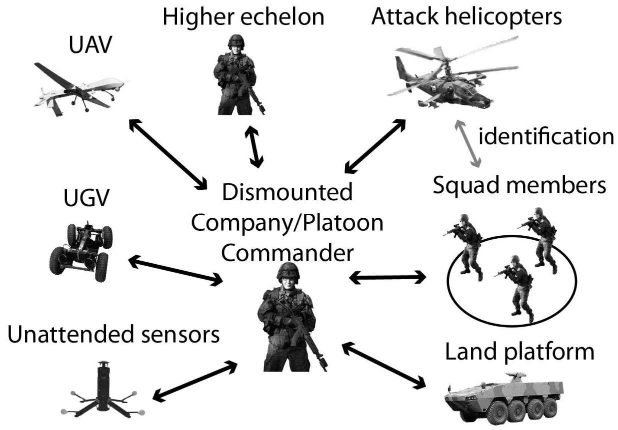

Figure 12. The types of possible platforms serving as sensors and network nodes [5].

The problems encountered in data distribution are linked to the present existence of various devices and data in interfaces. BML can be seen as a common language enabler between gadgets and interfaces [2] along with almost ubiquitous swarms of UAVs described in [15]. Limitations in energy and bandwidth play a vital role. The locating of instruments of various types consumes reasonable amounts of energy, not to mention the increase in weight and number of devices in warrior gear and required maintenance. Due to lack of accessible wireline infrastructures, unmanned systems have to be powered through a combination of batteries, solar power, and power scavenging [16]. When FSO-technology is adopted in backbone networks and between selected ground stations, an intelligent, dynamic and secure data transmission with high data rates can be offered to mobile end-user [17]. FSO-technology offers high-speed, reliable and cost-effective connectivity for heterogeneous wireless services provision in both urban and rural deployments when Dense Wavelength Division Multiplexing (DWMD) is utilized in Radio-on-FSO (RoFSO) system [18]. It has been demonstrated in tests that the advanced DWDM RoFSO offers a viable solution to provide broadband wireless connectivity. Radio over Fiber (RoF) technology will most likely offer a reliable data transmission rate of 10 Gbps in the next generation FSO-systems [18]. A simplified principle of FSO-communication system is introduced in Figure 13.

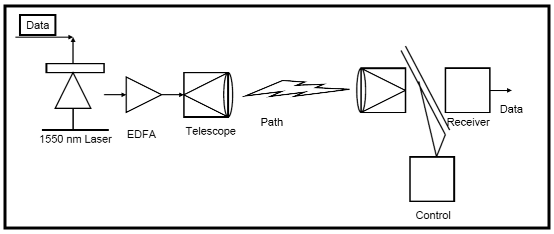

Figure 13. A schematic diagram of a point-to-point FSO communication system [19].

To maximize the possibility of devices communicating in a proper and planned manner, the topology of network systems has to be correctly coordinated (manage spectrum usage with group mobility patterns) [20]. In addition, the hierarchy of a network has to support and enable this. Both the goals can be achieved by hierarchical design where devices are only to interact with their peers from the same group [21]. Furthermore, the transmit antenna selection is a practical technique for achieving significant power gain, even with commodity hardware and without changes to different waveform protocols [13].

As discussed in light of usability cases presented in [16], WPSN is beneficial because of the following reasons: the effect of roadside bombs can be avoided once their precise location is known early and precisely enough. The increased knowledge at the basic warrior level in the form of location information gained from the Self-Calibrating Pseudolite Array (SCPA) on the battlespace improves warriors' ability to carry out the set tasks. Roadside bombs can be detected early enough and dismantled or destroyed before own or allied forces arrive on the spot. The Special Forces utilize the same output of SCPA while conducting their ultimate tasks. Since the nodes of WPSN do not communicate with each other, the system remains concealed, yet active. The WPSN node communicates with a UAV through encrypted messages. Thus WPSN responds only after a UAV has submitted a polling request with a specific code. Utilizing swarms of UAVs and UGVs has to be emphasized. The routes of UVs can be fed into the systems early enough to gain the needed information from the designated areas as depicted earlier in Figure 11.

VII. Location and Communication Possibilities in Urban Areas

An Army tactical warfighter needs network services both OTM and ATH [5]. One of the lessons learned from Iraq and

Afghanistan was the need for a more robust Beyond-Line-Of-Sight (BLOS) communication capacity between the lower Army echelon Land Warriors, from Squad Leaders to Battalion Commanders [5].

The proposed and described solutions have to be based on novel, generic and robust battlespace-proven solutions in order to meet the given needs, and this in turn involves addressing the topology of the network system carefully. In MOUT transmitting and receiving signals of different waveforms simultaneously is challenging due to the nature of the combat environment [22].

Since the power production and power consumption will remain as a challenge, certain issues need to be addressed. Thus when defining the network design, it has to be emphasized that network coding enables a more efficient, scalable and reliable wireless network [23].

The MOUT environment features no service of the Global Navigation Sensor System (GNSS) indoors, and indoors propagation poses a serious problem. The placement of an antenna platform is challenging. One solution can be the installing of a high-bandwidth conformal antenna in the soldier's helmet with the coverage of over 750 MHz through a 2,7 GHz frequency band [24]. The combat-critical solutions involve improving communicating, SA and transmitting C2 information among highly dispersed battlespace units in dynamic environments, such as MOUT [23] [24].

Next, let us assume that there is a WPSN-system available for positioning and location services. If the capability of GPS-Pseudolite, better known as the Self-Calibrating Pseudolite Array, is attached into the satellite-based Carrier-phase Differential GPS-type (CDGPS), it is possible to determine positioning in locations without access to the GPS satellite constellation [4] [15] [25]. This will improve locating own troops inside buildings dramatically, thereby significantly improving CID, TID and SA. This system is depicted in Figure 14.

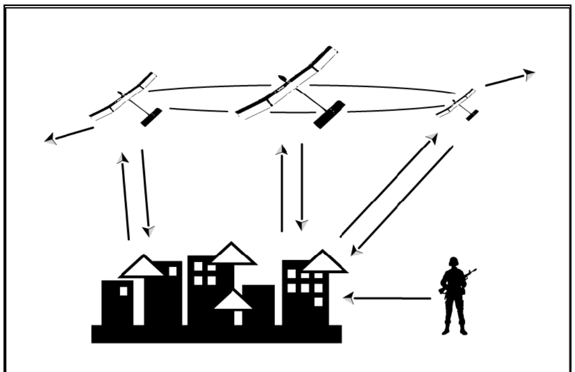

Figure 14. The WPSN presented in the urban infrastructure [4].

VIII. DISCUSSION

This study examines COTS-based communication technologies available for increasing dismounted FFW performance, minimizing collateral damage, improving SA and COP and focuses on how to apply technical solutions in the military environment to enhance the overall performance of a dismounted FFW. Applying suitable and relevant applications, C4I2SR tools in the existing networks, aids in overcoming the varying challenges in the battlespace [4][26]. Possibilities of Free Space Optics (FSO) can be utilized, as introduced in [19]. This study outlines aspects of applying the existing communication technologies, C4I2SR, to military battlespace systems [3]. In addition, the C4I2SR tools for dismounted FFWs have to cater for the requirements of affordability, reliability, versatility and modularity [4].

Means to present the accrued data are versatile and challenging. Since, as can be repeated ad nauseam, a warrior must primarily fight, the chosen method to present fused data has to support warriors' main task rather than disturb and distract. Especially, in order to be able to present SSA-data appropriately in battlespace settings, the assisting role and practical features of Graphic User Interfaces (GUIs) practically remain utterly important. This practical usability angle is depicted in Figure 15.

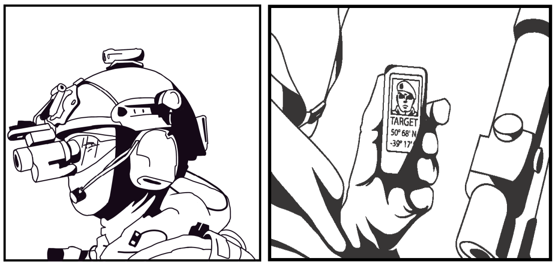

Figure 15. Means to forward the accrued data via various warrior displays.

In terms of the equipment angle to the FFW-concept, a properly equipped FFW represents a warrior who is supplied with the latest technology applicable which translates into enhanced performance capabilities in versatile terrain, including MOUT, CME and special operations. As evident, this asks for computer-aided modularity and scalability to allow for adaptability according to warriors' task-levels, timings, and locations of operations. Furthermore, the integration of subsystems must be possible in order to ensure the optimal functionality and accurate data transmission between the given systems. This requires that the equipment be rapidly replaceable and exchangeable for the purposes of location services and C4I2SR -systems.

As denoted in [7], asymmetric warfare sets more challenges compared to traditional warfare. This involves the challenges related to identifying the Point of Interest (POI) in the battlespace. It is essential to define the POI early enough as an enemy (red), own (blue), or neutral, White Force [27]. Before the execution of weapon systems, the commanding officer and a single Warfighter has to be in control of the given situation to avoid fratricide [28]. In case the POI is identified as an enemy, the decision of possible use of force has to be made rapidly [29].

An identification device utilizable in a battlespace consists of a transmitter and the receiver elements, the former based on laser, the latter on a radio frequency (RF) system. Warriors can be equipped with Cooperative Target Identification Systems. CTI allows a human shooter or sensor to interrogate a potential target and thereby forces the potential target to respond to the interrogation in a timely manner as described earlier in Figure 2 [5] [7].

As concluded in [12], the equipping of a FFW can be pictured by means of a product line warrior drawing from three-tier warrior levels. An FFW's gear has to be designed to meet the requirements set by the future hybrid battlespace [30]. Therefore, the warrior equipment must be versatile and modular. Moreover, remotely controlled UVs serve as tools to improve SA and BFT, and thereby assist in ensuring mission success [31]. The number and nature of different Human Machine Interfaces (HMIs) is growing with an increasing speed.

A computer can be adopted in varying roles depending on the warrior level in question: the computer can be mounted to clothing or on the wrist, for example. The higher the role of a warrior, the more a computer is seen as an assistant. In contrast, the lower the level, the more the computer forwards tasks. As presented in Figure 16, a computer can be programmed to task a warrior to move and fight at a certain pace depending on the mission. A computer can command a warrior to move at a certain pace and directions following the cycle of friendly fire missions as indicated in Figure 16. This process increases warrior efficiency, minimizes fratricide and increases a commander's SA.

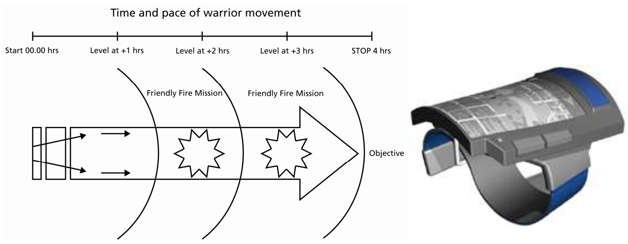

Figure 16. The principle of computer-tasked pace of movement (r) and a wrist module (l) [4].

Effect-based thinking and systems engineering serve as the tools to be deployed to achieve the ultimate goal: the optimally functioning effective FFW at all the command levels in all potential battlespace environments. Remotely controlled UAVs and UGVs can act as assisting tools for a warrior [32]. They can facilitate BFT and improve SA thereby increasing the probability of success in missions, even when operating Beyond Line of Sight (BLOS) [31].

According to [4], warriors have to remain functional and their gear needs to be planned according to their set tasks. A key factor is the efficiency of a warrior, which can be gained via improved SA, BFT and C4I2SR [12]. A Warrior has to maintain his or her agility and remain active in the battlespace. Furthermore, only part of the gear necessary can be attached. As demonstrated via the usability cases, WPSN solutions together with SCPAs and UVs can be utilized to reach the maximum performance at all the warrior levels. Planning the warrior's gear requires a deep understanding of the operational environments and the requirements set for the performance of a warrior.

As introduced in [12], the issue of exploiting C4I2SR-tools is not only a matter of a complicated command and control system [33]; it is a matter of trust in the entity, especially in operations utilizing collaboration tools of various types [34]. Each entity embedded into the C4I2SR-tool environment can contribute added value to SA and intensify the desired outcome by committing themselves to and abiding by the set rules and policies. Only this way C4I2SR -tools can be maximally exploited, and increase the number of promising instruments for the enhanced performance in ME and CME.

By being successful in merging all these described elements and tools, several C4I2SR -related challenges can be solved. As long as a human being serves in a loop as a performing entity, there will always be a certain amount of mistrust. Finally, once a reliable tool for distributing traceable tasks can be created, the amount of trust between entities can be increased.

As in [35], all the entities need collaboration for their mission success and survivability in ME and CME operations [36]. If an entity fails to collaborate, it takes a calculated risk to fail. Collaboration requires suitable tools and reliable and ubiquitous network systems [37]. Collaboration is necessary for avoiding chaos and avoid wasting resources in order to combine resources for an optimized outcome [37].

As demonstrated in [35], three results are offered as a contribution for the further development of Command and Control-tools: 1) a C2-tool, which enables use of Business Process (BP) in the command and control process; 2) the Resource Manager (RM), which is a central element of the Military Service Oriented Architecture (MSOA) in the distributing of limited resources; lastly, 3) the BP in the ME along with the MSOA [35], [38]. These results offer the yet missing attributes for the C2-tools for ME and CME. Combining these elements enables a successful control for the BP in ME and CME settings. Furthermore, [35] introduces the composition of the RM and the role of a scheduler, the function of the BP, and highlights the significance of trust and commitment in CME [35]. Trust is needed to gather information of the entities and to ensure tasks will be completed in the given time and manner [35]. Each entity embedded into the C2-tool environment can add increased value into the SA and thereby intensify the outcome by committing themselves to rules and abiding by the set policies. Understanding the meaning of combining the presented new tools gives an edge in the battlespace to perform more efficiently and with a minimum number of casualties.

As denoted in [19], FSO-technology offers a secure and reliable means to forward a constant flow of data with an adequate transmission rate [17]. Present communication systems on a warrior level are energy consuming and require a lot of training in order to benefit from the system [39]. The FSO-system in turn is simple to use, and thereby also less trained FFWs can effortlessly perform the necessary communication tasks. The overall reconnaissance system benefits from FFWs, individual sensors, sensor networks, and mathematical analyzing and data mining programs, resulting in high level data for increased SA [40]. The key function of an FFW is to collect large amounts of SA information and forward these data to the CP for further data analyzing processes. In brief, adopting FSO in active use allows for a system featuring high transmission security, high bit rates, low bit error rates, and no need for expensive optical or copper cables [41] and FSO can be utilized when using DWDM as introduced in [18]. The main limitations of FSO-technology are related to its susceptibility to the effects of atmospheric absorption, smoke, rain, fog, snow (attenuation), and pollution/smog and, obviously, a free line-of-sight [42]. These factors restrict FSO devices' range communication capability to cover approximately a mile in optimal conditions [41].

TABLE I. THE SYSTEM CHARACTERISTICS OF AND FUNCTIONAL REQUIREMENTS FOR THE FSO COMMUNICATION SOLUTION [19].

System Characteristics	Functional Requirements
Communication	High bit-rate, urban range in the usage scenario, hard to intercept and detect
Physical	Lightweight, low energy consumption, quick set-up
Architectural	Modularity, versatility, based on existing gear, suitable to Network Enabled Defence (NED), IP interface
Economic	Affordable, disposable, COTS-based
Dependability	Reliable, secure, proven technology
Capability improvement	Addresses a realistic capability gap (many relevant scenarios)

The WPSN-solution features many advantages over those of the traditional WSNs. This is, polling can use sensor specific codes and thereby security issues become easier to tackle [4]. Moreover, the energy consumption of the nodes in the fixed network is more equal since multi-hop data transmission is removed. The fixed sensor nodes do not lose connectivity even if a large number of nodes is removed [4].

As demonstrated via the presented usability cases [4], WPSN solutions together with SCPAs and UVs can be exploited to reach the maximum performance at all warrior levels. Planning an FFW's gear requires a deep understanding of the environment and the demands set for a warrior. The warriors' niche and the nature of their missions have to be thoroughly understood. The keys to success rely on precise planning based on the needs of warrior systems and subsystems from bottom to top

Obviously, in all military operations and especially in low-level tactical military operations in particular, critical Situational Awareness data have to be collected rapidly, since mission success is time-dependent. Figure 5 concentrates on describing the data accruing process, when Figure 6 expresses the outcome of MDPM as alternative COAs. Once data have been accrued, a battle can be won only by careful mission planning, comparing different COAs and rapidly executing successful operations.

Figure 8 earlier illustrates the process of targeting by utilizing the capabilities offered by the COTS-based SEM. Thereby the adoption of existing COTS-technologies and their solutions, when appropriately applied, offers a key to ensuring the desired success.

Since accurate and timely identification in the battlespace is a matter of life and death for each warrior, a careful analysis of the performance and capabilities of chosen systems needs to be carried out before introducing these systems in the battlespace. CID equals the process that warriors and sensors go through in order to identify battlespace objects prior to deciding whether or not to open fire. Warfighters are trained to employ all available means at their disposal to define and assess potential targets in the battlespace prior to applying combat power. CID can be seen as a complex series of networked systems, procedures and doctrine as presented in Figures 1 – 6. These systems also include the definitions of TTP, COP, SA, ROE and DIDEA.

More specifically, problems can arise in particular in commanding and being commanded. A Combat Identification Server (CIDS) offers military commanders and warriors access to accurate and near real-time BFT and WFT systems [5]. Besides this, CIDS offers commanders a tool which can foster improved mission planning resulting in increased accuracy and tempo of missions. To sum up, CIDS aids commanders to reduce the number of unexpected incidents and minimize collateral damage.

Once the TTP, CID, COP, and SA systems discussed in this paper (cf. Figure 1) are designed, tested and become fully implemented as part of the combat gear, some progress may be discernible in minimizing fratricide and collateral damage. The reality is that for as long as human actors remain part of any decision-making processes, incidents of fratricide and collateral damage are bound to occur. All efforts to minimize the human error factor by improving existing technologies, TTP, CID, COP and SA together with defining explicitly the formulations in ROE, are to be saluted. The efforts to minimize the unwanted phenomena are to be applied, for instance, in an ongoing series of Bold Quest exercises.

IX. CONCLUSIONS

In the very beginning of this study, the following three questions were raised: 1) How to optimize the performance of a dismounted FFW by means of improved SA? 2) How to increase SA with the available COTS-based communication technologies? 3) What are the means to avoid casualties, collateral damage, and fratricide?

First, as for the question of optimized dismounted FFW performance, regardless of the asymmetric and hybrid characteristics of future wars and conflicts with their respective battlespaces, combat settings necessarily involve a duel: participants try to surprise and outwin each other in terms of positions, timings, maneuvers, and technical capabilities. Defining suitable technological solutions as part of the FFW gear ensures the optimal FFW performance, which presupposes reliable and technologically mature C4I2SR-tools suitable for use in various battlespace environments with ubiquitous communication data transmitted with the solutions of NCW. An FFW functions in NCW contexts as a force multiplier of the network centric

C2-cycle from the sensor to the shooter aiming at minimized numbers of fratricide and collateral damage.

As for the elements necessarily part of the FFW-concept, the following features become seminal. FFWs with their computer-aided equipment need to be designed to meet the battlespace requirements dependent on their respective niche. Thereby the designing and constructing process of the FFW must be taken into account. To simplify, each warrior acts as a node or sensor and thus needs a reliable, versatile, modular and scalable electrical platform to receive and transmit the necessary data and information in a given operation- and task-dependent timeframe. Moreover, it needs to be possible to integrate subsystems to ensure the optimal functionality and accurate data transmission between the given systems, which in turn enhances overall warrior performance capabilities.

FFWs' functionality aims at improved overall performance and situational awareness (SA), which become evident in, for example, the instances of Blue Force Tracking, and Combat Identification (CID) facilitated by the capability to utilize data transmitted by UAVs and UGVs.

FFWs' personal computers' status is again dependent on the warrior-level in question: slave, assistant, or master. The role of the computer in all warrior levels is to enhance the overall SA, avoid fratricide and collateral damage and lastly but least, improve the performance of the warrior. Once the system that still currently remains to be designed is fully operational, a computer may order warriors to carry out an offensive in a particular direction at a given point in order to maximally utilize their performance capabilities. Since terrain requirements vary from remote locations or densely built-up areas to versatile battlespace, all the warrior equipment must be adaptable and able to support the warrior in the changing circumstances.

Obviously, the overall objective of planning and designing an optimally functioning FFW aims at avoiding fratricide and minimizing collateral damage. This ensures that all the resources available are focused on getting the ordered tasks fulfilled maximally. The end result then equals a state of Combat Effectiveness that enables a given unit to rapidly and accurately sort and characterize detected objects into relevant categories (blue, white, red), and, consequently, make a decision as to whether or not to employ force against the identified object / target.

Second, when it comes to improving SA by means of utilizing COTS-based communication technologies, challenges in CID continue to surface. As discussed, solutions for pinpointing and locating POIs can be based on COTS-technology. Yet, although the required technologies do exist, their usability still has to be tested and re-evaluated, and thoroughly selected solutions need to be adopted to avoid unnecessary casualties and destruction in the battlespace.

In terms of targeting, a more comprehensive targeting process can be attained with the assistance of UVs and UAVs. Once the targeting process is effective, it boosts the DIDEA decision making cycle. Moreover, by improving the targeting process, tools for better decision making can be offered. This in turn results in a better analyzing of COAs. Applying and properly executing the most favourable COAs facilitates are mission success with minimized number of fratricide incidents and collateral damage.

New technologies, such as FSO combined with WPSN can improve TID, CID, COP and SA. FSO offers a possible means to transmit large amounts of data to Command Posts with quick wireless set up. FSO also offers an insensitive and reliable means to improve the overall SA in ME and in CME. These all together support mission success and improves the overall efficiency in execution of versatile operations in rapidly changing operational environments.

As for the overall FFW gear development, extensive field trials with actual troops are required in order to test, validate, and evaluate the performance of the C4I2SR-gear. The focus of using these tools has to be in detection, identification and target acquisition processes. The capability to embed the required gear on the warfighter has to be combat proof. The interfaces between the human and the machine have to be designed, tested and evaluated to determine the optimal solutions to meet the set objectives. To ensure data distribution between various platforms, interfaces and machines problems in data distribution are linked to various devices. As noted earlier, BML can serve a common language enabler between machines and interfaces as well as a tool in exchanging data between and among swarms of UAVs.

In the future, the overall troop performance aided by assisting electrical devices has to be evaluated in varying environments, such as open terrain, MOUT, desert and forest terrain, and multiple scenarios have to be exploited as test-beds for realizing improved COP and SA. The level of the adopted gear has to match the existing chain of command and the task-based level and capability of the performing troops. Furthermore, the development of the user interface for the UVs remains a challenge. In addition, Graphical User Interfaces (GUI) are significant in maximizing the potential of the adopted and implemented gear. Thus extensive series of tests both in laboratories and as field trials are required to optimize the user-friendly GUIs.

There is an ever increasing need for more effective and versatile warriors. Armies of the world are downsizing their number of troops while requiring increased performance of the remaining military power, and, ever increasingly, versatile tasks along warfighting, including executing humanitarian missions, continue to set new requirements for warfighters and their capabilities.

And, finally, the bottom line here obviously targets the question of how to minimize casualties, collateral damage, and fratricide. As CID and TID systems continue to remain inadequate for battlespace settings, new COTS-based technologies and applicable solutions are both welcome and indispensable. As we speak, all the decisions as to whether or not to apply combat power boil down to a human being executing the decisions and owning the ensuing actions. Therefore any affordable means available must be exploited in order to be able to resort to applications and gear which truly facilitate improving the performance of dismounted FFWs, optimizing SSA and thereby reducing the number of instances which inevitably feature lives and assets lost no matter how honed the gear and minds involved.

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