Unmanned Aerial Systems as Tools to Assist in Digitalized Decision Making

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***Abstract*—This paper presents an idea-phase introduction of how to utilize swarms of Unmanned Aerial Systems (UASs) to assist the overall capability in digitalized decision making at company level and below. In military operations, access to analyzed data is crucial in optimizing the performance of the troops. This need for data access applies also in civilian settings, and therefore, this paper briefly discusses some use cases of UASs in civilian environments. UASs are used as hub-stations and tools to gather data from the areas of interest and to increase Situational Awareness (SA). Autonomous or guided platforms built with commercially off the shelf (COTS) material, UASs remain inexpensive data collecting tools. As the tempo of operations increases, a sustained capability for accruing timely and accurate data from a designated area is necessary for improved digitalized decision making. The aim in examining technologies and principles applicable both in military and civilian data gathering is to illustrate their applicability in both of these environments.**

Keywords-Unmanned Aerial Systems (UASs); dismounted company attack; real-time data; digitalized decision making.

I. Introduction

This paper is an extended version of [1] and examines at an idea-stage the utilization of Unmanned Aerial Systems (UASs) in decision making, reconnaissance and monitoring by means of implemented sensors on UASs. This discussion comprises use cases drawn from both military and civilian contexts. The difference between Unmanned Aerial Vehicle (UAV) and Unmanned Aerial System (UAS) is slight but this slight difference is important in that UAS also refers to the ground systems and not just the flying component. The fast and reliable method of collecting data requires that the collected data are transmitted to the base-station as timely as possible. This ensures that the data are available for decision making purposes within a minimal delay. Moreover, industry and regulators have opted for UAS rather than UAV as the preferred term to detone Unmanned Aircraft or Aerial Systems as UAS encompasses all the aspects of deploying these aircraft rather than the mere platform.

Militaries all over the world continue developing methods for saving the lives of own troops. The reason for this is the downsizing process of armies in western countries. In the environment where military operations are executed, a battlespace, the number of soldiers in combat units decreases, and simultaneously the number of personnel to take care of the logistics and maintenance issues increases as the maintenance of machinery utilized in the battlespace asks for ever increasing resources. The overall aim of militaries continues to be the sustained capability to improve operational performance despite the downsizing and minimized number of soldiers in combat. The remedy for this is an attempt to increase SA, which asks for the use of UASs to produce the required data for analyzing purposes.

In what follows, the preferred term is Unmanned Aerial Systems (UASs), including drones, unmanned aerial vehicles (UAVs), and remotely piloted aircraft (RPA), demonstrating the military use history that reflects this equipment's long-recognized potential in supporting warfighting efforts [2]. UASs represent systems that function as swarms and thereby enable effective collecting and transmitting of data.

UASs continue to be increasingly introduced in military operations. For instance, UASs exceed human-capability is that in Intelligence, Surveillance and Reconnaissance (ISR) [3], which involve dangers and unaffordable casualties. Without accrued knowledge from the Area of Interest (AOI), any army becomes incapacitated. Typically, UAS are utilized in operations that are characterized as being dull, dirty or dangerous (DDD). Also, UAS can be exploited in covert operations, and in research and environmentally critical roles. In addition, the economics of operation speak for the advantage of the UAS. Resorting to the performance of UAS can assist in minimizing human labour.

A company attack, typically a dismounted company attack, is a demanding military operation, which requires constant real-time data to allow executing all the phases of an operation to achieve the set goal. It comprises several phases of action, the first of which involves reconnaissance. An attacking unit must find out the composition and location of the opposite entity before a successful attack can be executed. Once the reconnaissance data have been gathered, the planning sequence of the operation begins by implementing the process of Military Decision Making

Process (MDMP). In this process, it is possible to benefit from automated assisting tools. When the MDMP has been carried out, it results in different types of Courses of Action (COAs). These COAs represent different alternatives to military commanders on how to organize the attack. Once the optimal COA has been chosen, the maneuver, dismounted company, attack can be ignited. A dismounted company attack is composed of the phases outlined in the following Figure 1: Assembly area, dismount line, line of departure, engagement, combat and the objective.

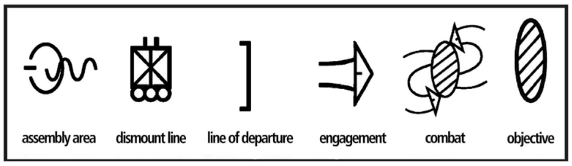

Figure 1. Dismounted company attack as a process [1].

To illustrate examining COAs, Figure 2 depicts two different types of COAs in a battlespace. The number of different COAs in real combat situation varies in that the number of COAs typically equals more than two, but to simplify things, in this case, there are only two COAs involved in the example depicted. In the first COA, the objective is to stop an armored enemy by deploying a flanking movement, whereas in the second COA, the objective is to destroy an enemy command post by direct engagement.

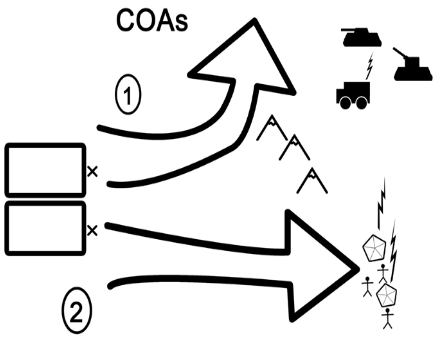

Figure 2. Different types of Courses of Action [1].

The utilization of UASs can be seen as having a central role when real-time data are required for rapid decision making. UASs can be viewed as a resource for military commanders in that UASs offer the advantage of surprise in an attack by producing the real-time data needed for decision making. If a commander fails in surprising the enemy, he or she loses the possibility to take the initiative in the operation. The ability to take and maintain the initiative is usually a prerequisite for a successful military operation, especially in a dismounted company attack. In order to facilitate an improved decision making process it is necessary to have access to the type of data that are necessary and most updated.

The utilization of UASs is necessary to get the correct information from enemy space as rapidly as possible in the hectic tempo of operations, save soldiers' lives and support the morale of troops performing the maneuvres in an operational area. Furthermore, the use of unmanned equipment can be seen as part of optimizing the existing resources of military units as machines ceaselessly continue fearless fighting.

When militarily utilized, UASs can be used for varying tasks: performing terrain reconnaissance in the area of objective, performing reconnaissance of the use of Nuclear, Biological and Chemical substances, maintaining reconnaissance engagement by providing data on enemy movements, and monitoring the actions of enemy troops (direction and speed of movement, location, size, formation, action). UASs can also be utilized in the targeting process in that UASs can be sent airborne to the designated areas for the reconnaissance and targeting of the potential enemy targets. UAVs can act as relay stations for sustaining the constant capability to communicate and control the troops and machines in the hostile area.

Collected data from the designated areas are utilizable in the MDMP that is linked to gaining SA and choosing between different COAs. These data can be collected more safely, if an appropriate number of UASs of the necessary type are available for these operations. Using UASs alongside with dismounted close combat soldiers to complement data gathering makes it possible to combine optimally the capabilities of soldiers and equipment. The latter can be sent out to the most dangerous locations while dismounted close combat soldiers remain in charge of the less lethal task, if ever possible in a battlespace.

The use of UASs gives an advantage for commanders. First, UASs can be sent to the areas of interest, days ahead, if required. UASs can be shut down or reactivated via electrical signals when necessary. This gives commanders the advantage to transport the UASs as reconnaissance resources to the designated areas timely at the chosen moment. When UASs have been flown to the area and shut down, they will not consume any energy, and the saved energy can be used at a chosen moment and in the wanted operation, which supports the own battle plan and own objectives. Commanders are able to plan these actions prior to execution and have UASs transported to the areas when deemed appropriate and safe. UASs can be ready and standing by in a chosen area, with the chosen sensors embedded in the UAS platform.

To summarize: commanders can benefit from the use of push and pull factors. Commanders can push the UASs to the optimal area of battlespace at a chosen moment. The optimized location of UASs may then guarantee the improved performance in own oncoming military maneuvers. The pull factor means pulling the data from the designated areas at a chosen moment. These data are pulled to increase the performance of own operations in analyzing the collected data. The collected data serve as raw material for defining SA and COP. The accrued data are utilized in the MDMP and in the process of choosing between different COAs.

A network structure offers a new and ubiquitous way to share and forward all kinds of data, including data collected by various sensors, the Wireless Polling Sensor Network (WPSN) was introduced 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. Communication is critical in the execution process of command and control. When the possibilities offered by the Wireless Polling Sensor Network are taken into active use together with using One Time Pads (OTPs), two communication goals become achievable: the covert network and security in messaging. This is discussed more in Section VI.

When machines, such as UASs, are utilized, Service Oriented Architecture (SOA) becomes applicable. In digitized battlespace and in digitized operational planning, SOA is utilizable in allocating processes of own existing resources and optimizing the use of troops timely and in the correct operational area. SOA is also useful in offering assistance in the overall planning process. SOA can be used in optimizing the timing of the different actions, also while the dismounted company attack is in progress, and in automating the MDMP. By automating the MDMP and using UASs, commanders can save time, resources and lives as well as achieve the set objective.

In both military and civilian operations the need for updated analyzed data is equally important. The means utilized for collecting data on areas and targets of interest are identical as well.

The rest of this paper is organized as follows. Section II concentrates on the related work, Section III discusses the characteristics of Unmanned Aerial Systems, and Section IV targets the essence of practical communication. Section V deals with Wireless Polling Sensor Networks and the use of One Time Pads, Section VI deals with Military Decision Making Process, and Section VII tackles Situational Awareness and Common Operational Picture. Section VIII discusses the significance of sensors, and Section IX looks at SOA in relation to MDMP and reorganizing the chain of command in troops. Section X concentrates on possibilities offered by new technologies, Section XI comprises discussion, Section XII concludes with the results, and Section XIII addresses requirements for further studies.

The main contribution of this paper is the idea phase and conceptual level description of how the data accrued with the assistance of UASs can be implemented into a decision making process and how these collectd and analyzed data in turn may enhance the results gained by means of a military decision making process. Also, improved situational awareness and common operational picture contribute in facilitating collective performance that can be identified as the overall performance capability in the execution of processes. Finally, this paper introduces idea phase methods on how to improve the process of automatic data gathering with the assistance of UAS and how to increase inputs towards automated decision making processes and towards automized military operations.

II. Related Work

The importance of UASs both in military and civilian environments has been recognized and several studies have examined the overall performance of UASs in civilian settings. For instance, data acquisition for post-disaster assessment has been studied in [5]. Furthermore, [6] studied using UASs for inspecting structural damage caused by hurricane and concluded that UAVs have great potential for post-disaster data collection and assessment. The identified challenges included obstacle avoidance, site access, sensor coverage and weather conditions.

Moreover, civilian use cases of using UAVs include obtaining data on traffic trends and monitoring and controlling traffic in real-time to ease the traffic flows in risky areas, as indicated in [7]. In case of an emergency the pinpointed crash-site can be fast recovered and the injured evacuated.

UAVs have also been used for data acquisition for management and monitoring purposes in gas-pipeline inspection [8] with sustained UAV flying capacity for several hours.

Preparations for potential disaster-related usage of vision-based UAV navigation have been identified as an important factor in UAV navigation, see [9]. In this study, an algorithm was developed to identify structures within the UAV-collected imagery and navigation directives based on these structures were relayed back to the UAV.

The main challenges with UASs are linked with the limited communication ranges. This issue has been identified also in [1]. UASs have successfully been used in detecting different types of Points of Interests (POIs). The use of UASs in search and destroy missions has been challenging, as pointed out in [10]. The main challenges involve the communication process between the UASs [10]. The problem was solved by creating a new coalition formation algorithm to enhance the communication among the UASs.

In addition, UASs offer a more inexpensive solution than human-operated helicopters for monitoring high-voltage transmission lines [11].

As for the military use cases, several researchers have been studying the use of UASs in accruing data to support SA, COP and MDMP by increasing the performance of different types of networks. Moreover, the studies listed here have concentrated on increasing the speed, safety and capability to communicate in an improved manner.

As demonstrated in [12], ad-hoc networks can create a UAS access net ensuring communication among mobile or stationary users. These ad-hoc networks support Blue Force Tracking, as indicated in [13]. When UASs are equipped with Free Space Optics (FSO) communication links, operations can be executed by avoiding to become sensed by means of electrical reconnaissance detection, as concluded in [14]. FSO represents an optical communication technology that uses light propagating in free space to transmit data from point-to-point (and multipoint) by using low-powered infrared lasers, which can also be used for localization purposes, if range and orientation information is available FSO-technology offers high-speed, up to 10 Gb, 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.

In vision-based tracking, pan-tilt gimbaled cameras using Commercial off-the shelf (COTS) components can be used together with calculation algorithms and advanced controlling systems for integrated control of a UAS and an onboard gimbaled camera, see [15]. Along with the availability of both low-cost and highly capable COTS-based UASs and Unmanned Ground Vehicles (UGVs) and communications equipment, it is reasonable to apply quick and inexpensive means for surveillance, tracking and location purposes, as discussed in [16]. UASs of varying types and sizes can be used in aerial surveillance and ground target tracking, see [17]. To boost the performance of a single UAS, swarms of small UASs can rely on airborne MANETs, as indicated in [2]. Transmission antennas are significant in the process of operating UASs, as indicated in [18]. When swarms of UASs are utilized for navigation, localization and target tracking, information synchronization is important, as discussed in [19]. In present battlespace miniature UASs are becoming increasingly significant among surveillance applications, as shown in [20]. Remotely controlled UASs can act as an assisting tool in tracking and monitoring, as discussed in [15]. Remotely controlled UASs can enhance SA, Blue Force Tracking (BFT), thereby enforcing the probability of success in missions, even when operating beyond line-of-sight, see [21]. The means for exploiting UASs and UGVs in the processes of data collection and the distribution of an updated COP to be implemented in Shared SA are discussed in [22]. Battle Management Language (BML) can be seen as a common language enabler between machines and interfaces along with almost ubiquitous swarms of UASs [19]. For example, networks utilizing COTS components mounted on of UASs add survivability and remove the need for a line-of-sight connection, as described in [16].

This present paper examines how to facilitate a dismounted company attack with the use of UASs. This means aiming at optimizing the use of existing resources and automating an attack to the extent feasible. The objective is to contribute to the overall goal of increasing safety in military operations by means of improved use of resources resulting in decreasing numbers of casualties as well as increasing the tempo of own military operations.

The same calculation parameters and algorithms are utilizable both in military and civilian data collecting systems. This same applies to data transmitting systems.

III. CHARACTERISTICS OF UNMANNED AERIAL SYSTEMS

Unmanned Aerial Systems utilized in a dismounted company attack can be autonomous or guided platforms built with COTS material ensuring the relatively low price tags on the UASs. The main function of UASs is to produce real-time data for commanders for decision making purposes. The use of swarms of UASs ensures the gathering of data behind the visual horizon. The distances between command link and the swarms of UASs are typically few kilometers. Once identified by the actions of an adversary, a UAS ends up becoming annihilated. Therefore, UASs have to be built to be disposable elements. When the UASs are used as swarms, the combat survivability of the system can be increased.

Some of the promising characteristics of the UASs involve long flight duration, improved mission safety, flight repeatability due to improving autopilots and reduced operational costs, especially in military environments, compared to manned aircraft. The potential advantages of an unmanned platform, however, depend on factors, such as aircraft and sensor types, mission objectives, and the UAS regulatory requirements for operations of a particular platform [2].

For the purposes of this paper, measuring the utilization of UASs in a dismounted company attack would require real functioning swarms of UASs. Creating a simulation to model a UAS assisted operation is at present, unfortunately, non-feasible on the grounds that neither funding nor facilities are available.

In Network Centric Operations (NCO) it is seminal to ensure identifying and defining relevant information to enable its distribution in the battlespace. This presupposes timely and secure information flow between own warriors and sensors [23]. UASs have to be used for collecting all the data available in the battlespace. Contemporary weapon systems require greater amounts of intelligence data at a higher accuracy level than ever before [13]. Since operations tend to be multi-national, different sensors and systems are required to communicate understandably between each entity. This means that all the participants representing different nations must agree on the wavelengths, frequencies, and waveforms to be utilized in the transmission processes between the sensors and base-stations. Various entities and nations typically utilize different types of signals and waveforms for varying reasons, and the utilization of the radio magnetic spectrum must be settled before a multi-national operation can be successfully executed. This is necessary to minimize instances of fratricide and collateral damage, which requires the maximized distribution of the updated COP. One solution for this involves utilizing Business Management Language (BML) [23].

As for the classification of UASs, the types of classifications vary depending on the source, as in [24]. A classification based on size includes the sub-classes of Small, Medium and Large UASs. The class of Small UASs can include Very Small UASs, which in turn can include Micro or Nano UASs and Mini UASs, whereas the categorization of UASs according to their travel ranges and endurance in the air include the following sub-classes developed by the US military: Very low cost close- range UASs, Close-range UASs, Short-range UASs, Mid-range UASs, and Endurance UASs. Table I below lists varying types of UASs.

Especially in civilian applications, UASs can be identified as collectors of data in ecological, meteorological, geological and human-induced disasters. UASs can be seen as versatile tools in data gathering for their flexibility, safety, ease of operation and relatively low-cost of ownership and operation. This facilitates UAS implementation in disaster situations, as described in [5].

This paper discusses only UASs because of their versatility compared to other Unmanned Vehicles (UVs), such as Unmanned Ground Vehicles (UGVs). When a small tactical level military unit, such as a company, is performing a complicated maneuver, a dismounted company attack, the UASs represent the only reasonable type of UVs to be utilized.

The following Table I lists a classification of types of UASs built for varying purposes.

TABLE I. TYPES OF UASS

Type of UAS	Abbreviation	Altitude (meters)	Flight time / Distance (km)	Payload	Example of an UAS
Micro-Air Vehicle	MAV	Low <330 m	5 to 30 minutes / kilometers	10 – 200 grams	Mosquito, Carolo P50
Low-Altitude Short Endurance	LASE	<1000 m	1 to 2 hrs / few kilometers	200 – 500 grams	Dragon Flyer X6 VTOL
Low Altitude, Long Endurance	LALE	from 2000 to 4000 meters	several hours /tens of kilometers	up to several kilograms	RQ-11 Raven, Skylark
Medium Altitude Long Endurance	MALE	up to 9000 meters	+24 hrs / hundreds of kilometers	over 1000 kilograms	Ikhana, Heron 2, Predator B
High Altitude, Long Endurance	HALE	up to 20 kilometers	over 30 hrs / thousands of km:s	over 1000 kilograms	Global Hawk

UASs are capable of monitoring the designated target areas and transmitting real-time data to the base-station simultaneously when monitoring the area (see Figure 3).

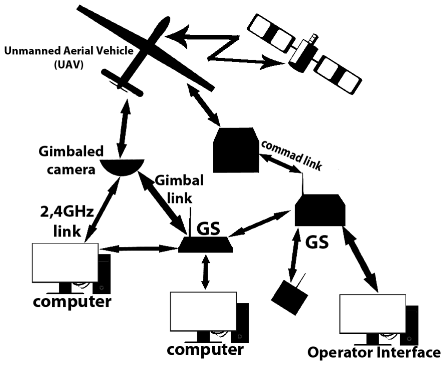

Figure 3. UASs and the data transmission [1].

When flight times are short, less than an hour, engines and sensors embedded into UASs can be powered by liquid fuel batteries to ensure adequate level of energy. Liquid Polymer (LiPo) batteries are utilizable for their capacity. Electrical surveillance components, guidance systems, and command systems depend on adequate electricity level.

Typically, the distance between a communication link and a swarm of UASs is few kilometers, and therefore 2.4 GHz Ultra-Wideband Network system between the communication link and the base station is applicable for these distances. The usual speed of swarms of UASs is tens of kilometers per hour. This is a chosen speed to balance the energy consumption and the range of transmission power and movement.

UASs are most versatile with their capability for quick deployment. UASs tend to be miniature-sized airplanes, drones and helicopters, weighing few kilograms. The range of these vehicles can vary from few hundred meters to few kilometers as can their mass and size. The same applies to the payload. The payload can be measured from tens of grams to few hundred grams depending on the use and measurements of UASs.

The typical payload of UASs can comprise varying sensors, such as: acoustic-, seismic-, magnetic-, visible image-, shortwave infrared (SWIR)-, thermal-, infrared-, low-light television (LLTV)-, and sensors for laser tracking and spotting, and for facial recognition. These sensor packages can be also deployed into the area of interest at a desired moment. If the area of interest is known well in advance, a UAS and the sensor package can be flown into the perimeter in advance and been dropped in the chosen area. In addition, a UAS can be guided close to the area of interest. The UAS can then be parked, for example, on rooftops and cliffs to wait for the command to start the reconnoitering mission. This saves time and positions the UAS in nearby perimeters of the desired area. The UASs remain hidden and hard to detect, and when detected, it is too late anyway.

In versatile combat situations, different types of Combat Information Systems (CISs) implemented by sensors are important parts of military command and control environment systems [25]. Raw reconnaissance data remain critical for creating a comprehensive Situational Awareness and Common Operational Picture. Without constant flow of intelligence and surveillance data, successful military operations cease from existing.

The significance and potential of miniature UASs has been discussed since the beginning of the past decade. Today, miniature fixed-wing UASs are mainly used to target drones, for surveillance, and as decoys [26.].

Examples of target drones do not belong to the category of miniature fixed-wing aircrafts, but they are full-scale target drone types, such as FQM-117. Target UAV series include three members: MQM-117A, MQM-117B and MQM-117C.

In terms of reconnaissance drones, a famous example is RQ-11 Raven UAV. As for decoy drones, identifiable are Israeli manufactured Firebee 1241 and Scout.

For civilian purposes, the main uses of UASs include internal security, for instance border patrol, victim search and rescue, research, wildlife and land management, and agricultural maintenance processes.

IV. COMMUNICATION BETWEEEN ENTITIES

The amount of data accrued via versatile sensors and tracking systems is vast. 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 the monitor of their palm-top or equivalent. Besides, there will always be disturbances in the electromagnetic spectrum, quality of service (QoS) and transmitting power along with the limited bandwidth set limitations to the ubiquitous communication systems. However, the possibilities of battlespace communication are versatile, since almost all the sensors utilized are somehow linked together to facilitate BFT and Combat Identification (CID) and to improve COP and SA. UAS can be seen as a functional tool in the process of accruing data, see Figure 4.

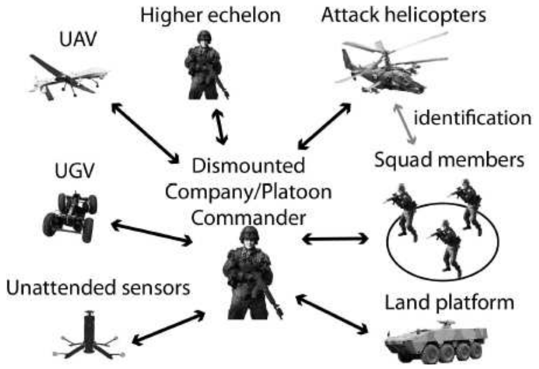

Figure 4. Data accruing process in brief.

When UASs are utilized in operations, the significance of communication links cannot be overemphasized. UAS are extensively used in exploration missions. They are used routinely to collect and send collected data back to ground station that provides real-time information on the covered area. Printed antennas can be seen as a solution in UASs. As described in [27], the significance of a functional printed antenna has been successfully tested and reported concerning a study in which printed antennas were used in computers for wireless local area network (WLAN) connectivity in the frequency of 2.4. GHz ISM (802.11b.g) and the 5 GHz (802.11a) bands. Printed patch antennas are widely utilized in automobiles as antennas for receiving signals of the global positioning system (GPS) and also in satellite digital audio radio systems (SDARS). These systems pose acceptable gain and radiation efficiency, as described in [28].

The capability to communicate between troops (soldiers) and machines (UASs) must be sustained throughout an operation. Without communication there is neither command nor control between the entities. Communication can be described as comprising three layers. These layers are sensor-layer, C^4I^2SR –layer and shooters –layer. The layers are connected with the existing communication networks. Different layers are depicted in Figure 5.

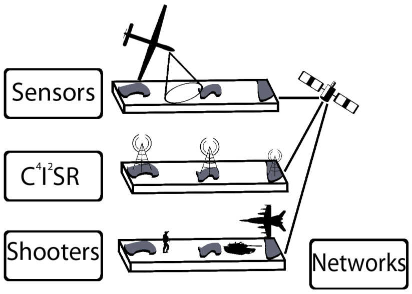

Figure 5. Communication network from sensor to shooter [1].

The depicted layers communicate and forward data via UAS–radios, which can utilize the output of GPS/GLONASS receivers for automatic position reporting. When Software Defined Radios (SDRs) are embedded onboard UASs, typical SDRs' features can be included into transmission protocols. These 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, updated and analyzed data transfer from sensor to decision maker and onwards to the shooter applications. Lightweight UAS–implemented radios offer low consumption transceivers operating in the frequency of 2.4 GHz Industrial, Scientific and Medical (ISM) band. The use of this frequency offers very low Radio Frequency (RF) signature modulation scheme based on spread spectrum technology (DSSS) and provides 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. UAS -radios can provide several tactical communication services: full-duplex voice conferencing, GPS reporting, e-mail, chat, file transfer, and real-time video streaming.

When properly adopted into active use, UASs can be seen as flying hubs or flying relay-stations, tools of communication. When UASs are used to secure communication, as depicted in Figure 5, the throughput of communication can be maximized. Furthermore, the swarms of UASs end up creating an own data communication system, as depicted in Figure 6. This ensures that the data transmission distances between UASs remain short and become operationally secure. This aids in meeting the requirements of Low-Probability of Detection (LPD) and Low-Probability of Identification (LPI). The described delicate system introduced is a new one and based on ideas that can be executed by utilizing existing COTS- technology [29].

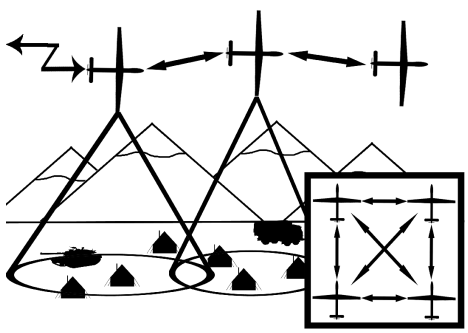

Figure 6. A data exchange process inside the swarm of UASs [1].

Figure 5 describes the idea of using UASs as swarms. The number of UASs used in each scenario varies depending on the commanded mission and its speed and other set requirements.

V. Wireless Polling Sensor Networks

A battlespace tends to be embedded with different types of sensors found from the soil, airborne or attached into various types of manned and unmanned vehicles. The utilization of Wireless Polling Sensor Network (WPSN) together with One-Time Pads (OTP)s can be viewed as one possible solution for the improvement of a communication system between sensors and UASs. In the case of UAVs and other easily captured nodes there is a special disadvantage in using ordinary crypto algorithms requiring a stored key. Furthermore, neither the time nor the computing power is available for asymmetric algorithms. A solution to this problem is presented by a novel idea of exchanging One-Time Pads and encrypting data with one of the OTPs. One-time pad (OTP), or Vernam's cipher, is a crypto algorithm where the key is as long as the plain text. The modern version of the algorithm simply takes a bitwise exclusive or of the key and the plain text. The idea is explained in [30].

The other OTP must be discarded for security reasons WPSN can be viewed as one possible solution when gathering data from different sensors and sensor networks. When a swarm of UASs is utilized in forming an ad-hoc network and polling a large number of fixed sensor nodes, a secure network system can be created. The WPSN system is more robust in the military environment than traditional Wireless Sensor Networks (WSNs). Although WSNs have been used for a long time, they demonstrate particular disadvantages. These include the fact that multi-hop transmission fails when nodes are destroyed in military environments, battery lifetime creates limitations, and security challenges remain unsolved. A WPSN has advantages in all of these areas compared to other proposed solutions. WPSN comprises a small mobile ad-hoc network of UASs and a high number of fixed ground-based sensors, which are periodically polled by the UASs.

The advantages concerning WPSN and OTP include that in the WPSN solution the fixed sensor nodes remain concealed, yet active, because the sensor nodes of WPSN do not communicate with each other but only respond to polling by the mobile nodes. The WPSN node communicates with a UAS through encrypted messages. Thereby, WPSN responds only after a UAS has submitted a polling request with a specific code. The routes of UVs can be fed into the systems early enough to gain the needed information from the designated areas [30].

When speaking about a battlespace and actions taking place in this hostile environment, it is mandatory that some of the UASs be shot down or destroyed by other means of contemporary warfare. This possibility must be recognized prior to engagement. UASs must be designed so that once malfunctioning, they will get automatically destroyed (software and hardware) to become instantly useless for the adversary. Yet, this destruction of one UAS does not jeopardize the concept of sustained secure communication, for the network composed by remaining UASs will reroute itself automatically.

By exploiting WPSN and OTP it is possible to utilize UASs as described above when gathering data both in military and civilian environments. Especially the using of OTP increases operational security in both of these digitalized environments.

VI. Military Decision Making Process

In military operations performed at tactical level, i.e., battalion and below, the significance of tempo and timing becomes critical. In the MDMP all the raw data collected by UASs have to be analyzed and taken into account as they are directly connected with targeting systems, weapon selection processes, COP, SA and Control, Command, Computers, Communication, Information, Intelligence, Surveillance and Reconnaissance (C^4I^2SR).

Here, automation and mathematics can be seen as assisting tools in the process of making rapid and reliable decisions. When mathematical methodology is implemented, measuring the additive value model is the simplest and most commonly used mathematical model in multiple objective decision analysis. As described in [31], the additive value model is given by the equation:

$$v(x_j) = \sum_{i=1}^{n} w_i v_i(x_{ij}) \qquad (1)$$

where

$v(x_j)$ is the total value of alternative *j*,

$i = 1$ to n are the value measures specified in the qualitative value model,

x_{ij} is alternative *j*'s score (raw data) on value measure *i*,

$v_i(x_{ij})$ is the single-dimensional value of alternative *j* on value measure *i*,

and w_i is the swing weight of value measure *i*.

Equation (1) is the simplest and most commonly used mathematical model in multiple objective decision analysis.

Obviously, mathematics alone cannot solve the dilemma of making the correct operational decision quickly in a chaotic combat setting. When a decision is made between different COAs, mathematics and probability prognosis can only be seen as assisting tools. The human commander remains the only one who is responsible for sensible and applicable decision, which can be converted into commands to be issued and executed in an operation.

VII. Situational Awareness and Common Operational Picture

The term Situational Awareness has been given an apt definition in the Army Field Manual 1-02. SA can be understood as 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. SA, furthermore, equals an informational perspective and skill that fosters an ability to determine quickly the context and relevance of events that is unfolding. The term SA comprises three levels: 1) perception, 2) comprehension and 3) projection [32]. SA, or, the lack of it, remains critical in performing military operations successfully. The means to increase SA can and must be fostered and developed, since the loss or deterioration of SA results in inaccuracies, human errors, and eventual casualties and fratricide. The military operation in progress usually fails because of poor level of SA.

Situational Awareness has a strong relation to COP. COP represents an overall understanding of the prevailing situation in the battlespace. COP can be displayed on the screen of a computer or a digital device, and by using markers and traditional maps. COP features elements, such as individuals of friendly forces, neutral entities and the adversary, presented by symbols of various types.

To complete the list of phenomena affecting the MDMP, C^4I^2SR needs to be taken into account. UASs are utilized to assists the MDMP performed in C^4I^2SR environment. When combined together as swarms, UASs form tools for accruing data, forwarding and analyzing these data into the form of information to create COP and increase SA.

To sum up, all these listed elements are linked to the MDMP. The decisions made as part of the MDMP can also be seen as tools in targeting and weapon selection processes. Figure 7 explains the relations and functions inside MDMP when the use case is related to targeting and weapon selection systems. In the MDMP, the end-come is the optimal use of weapon systems to avoid collateral damage and fratricide.

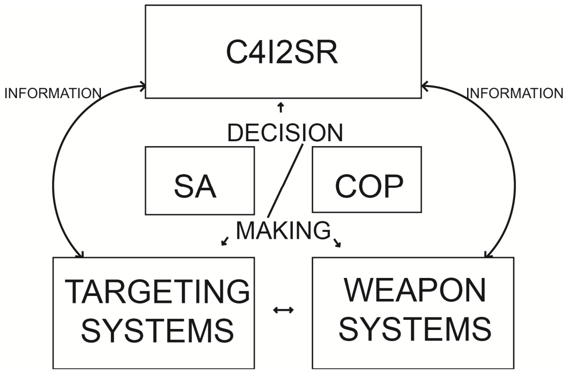

Figure 7. Decision making system in targeting and weapon systems [33].

VIII. SENSORS

In order to achieve the set objective in a given military setting, it makes sense to utilize maximally the data produced by various types of sensors when accruing data from hostile environments. In some cases, especially when the weather conditions are challenging, for example, the wind speed exceeds 10 metres per second, the UASs cannot be used or they are too slow and there has to be an alternative possibility to deploy sensors for accruing real-time data. Some of these sensors can be deployed to the area of interest with the assistance of artillery fire produced by mortars or cannons. Rapidly deployable airborne sensors represent relatively inexpensive and versatile tools for low-level battalion and company operations. As indicated in [33], light sensor munition can be deployed behind enemy lines, and an example of sensors' deployment, when UASs are not applicable, is Sensor Element Munitions (SEMs). SEMs can be manufactured of composites surfaced with materials capable of absorbing radar beams, making the SEM less visible in enemy counter-artillery radars. In any military operation, airborne sensors are important for missions, such as force protection, perimeter control and intelligence utilization, as discussed in [34]. Transmitting the accrued data to prevent cases of fratricide and to ensure success in operations presupposes optimal communications. WiMAX transmission offers applicable possibilities in forwarding collected data. The distances in the transmission process are relatively short, ranging from 1 kilometre to few kilometres in conditions of clear Line-Of-Sight.

The sensor package inside sensor element munitions is named Sensor Element (SE), which is made of COTS-products comprising sensors capable of sensing most of the phenomena occurring in the electromagnetic spectrum. Overall, COTS-products are relatively inexpensive and reliable in terms of function, as explained in [35]. Sensor Elements can contain the same sensors as UASs. The command post has the capability for the data fusion of all the accrued sensor information.

Once an SE is airborne, it immediately starts to transmit the gathered data to friendly troops either directly or, if the transmission distance exceeds the capability of the transmission unit, the SE transmits the data to another airborne device, which acts as a relay station in relation to own troops. The SE communicates with the receiver station and other sensor element packages over a 2.4 GHz Ultra-Wideband Network system. The accrued data are encrypted for security reasons. The composition of SEMs is depicted in Figure 8.

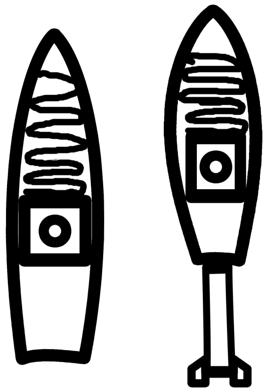

Figure 8. Structures of Sensor Element Munitions (SEMs): An artillery SEM (left), a mortar SEM (right) [33].

SEMs can be deployed to the target area with manned artillery weapons or unmanned remotely controlled pieces of artillery or by using mortars, as mentioned earlier. The process of deploying SEM to the area of interest is depicted in Figure 9. SEM ejects the Sensor Element, which in turn reports the gathered data to the base station [33].

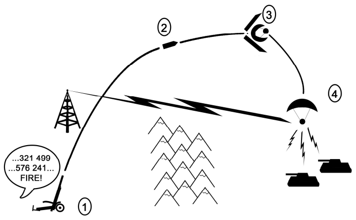

Figure 9. Process on how to deploy an SE to an enemy territory [33].

In Signature Prediction Process (SPP), described in [33], sensors accrue data and transmit these data for analysing centres. These data collected with SEMs are then verified with the data collected with other sensors in order to predict and anticipate the target and its actions. These data can be also utilized in analysing different possible courses of action and in the weapon selection process.

When we implement a weapon of any kind as part of the unmanned aerial system, we are dealing with an Unmanned Combat Aerial System (UCAS). The route planning of a UAS or Unmanned Combat Aerial System (UCAS) is in a significant role when an operation is in its planning stage. The same applies to the significance of algorithms in time limited operations, as indicated in [36]. The reconnoitering range tends to vary from one to few kilometers. When a dismounted company attack is supported with units of UASs tailored for Close-Air Support (CAS), the data exchange transmission process for the target data is depicted in Figure 10.

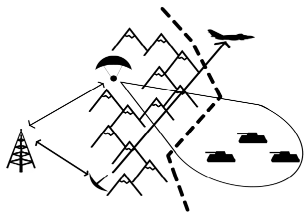

Figure 10. The process of detecting target to the shooter [33].

The UASs of CAS units optimize the speed and destruction power used in proximity to destroy the designated targets. When a small unit operates, it needs to achieve results in short time in order to maintain the initiative and reach the set objective. A company is a small military unit, which has to maximize the momentum offered by the performance produced by CAS units. UASs must be utilized as tools to evaluate the outcome of the executed CAS fire-mission. If the result of CAS fire-mission is reported not to fulfil the requirements set, the new round of CAS fire-mission must be performed to destroy the chosen target.

IX. Service Oriented Architecture

SOA offers a variety of possibilities to improve the performance in military operations. When UASs become more increasingly identified as an exploitable resource in the military data producing environment and as the inputs of the UASs become fully utilized operationally, SOA is going to render itself useful for military commanders in executing military operations. SOA can be exploited when needing to reorganize the military organization after casualties affect the chain of command in a dismounted company. This process is described in [37]. Military operations nowadays usually demonstrate features of Network Centric Warfare (NCW) in which one key aspect is to be able to offer a valid and accurate COP for the operating troops in the battlespace. A basic requirement for a military commander is the ability to command the troops and sustain optimal SA and COP. An important aspect in distributing information in the battlespace is the amount and quality of information shared at different levels. SOA can be seen as a useful tool in distributing data in a preprogrammed manner. The amount of information allocated must be set to a level where the decision maker can perform timely and draw accurate conclusions. In the battlespace, the units suffer from casualties and the chain of command never remains intact.

A constructive idea in SOA is in its process ideology. In a dismounted company, the composition of the unit and its performance are critical in executing the operations. Military units suffer from casualties and their mathematical performance value tends to change in an unpredictable manner. The performance of a military organization, such as a dismounted infantry company, can be mathematically calculated as explained in [37]. Behind these mathematical values is a Psycho Physical Factor, described in [37]. The process of creating this factor is described in [38] and the formula may be useful in calculating the performance of a military unit.

The implementation of SOA is described in [37]. A key aspect in the presented architecture [37] is the dynamically changing architecture. Benefitting from the possibilities offered to orchestrate data and services with the assistance of SOA allows for improved performance in the execution of operations. SOA can be utilized in the process of choosing between different COAs. Eventually, the chosen COA will be fine-tuned into commands and maneuvres of a dismounted company attack.

In applying SOA paradigms, loose coupling, dynamic binding and independency of development technologies, platforms and organizations, as well as locations, all these become advantages in that the use of SOA typically encourages reusing services. The identified assets belong to military units, but military units offer their responsibilities through services, and capability deployment requires invoking and integrating a number of services. Figure 11 depicts the relations of services, assets and capabilities of a military unit.

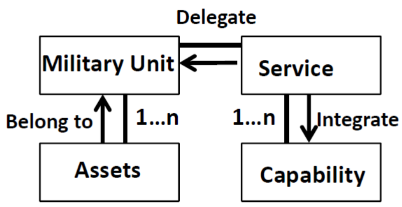

Figure 11. Conceptual model of C^4I^2SR capabilities based on SOA [39].

In a dismounted company attack, all operating military platoons use the same services and assets of a dismounted company. In this case, SOA itself offers a flexible approach to identify C^4I^2SR capabilities when several platoons benefit from the services and assets of a dismounted company. SOA enables a company to respond more quickly to the changing battlespace situations and requirements to execute the given missions in the given time and with the allocated resources.

X. POSSIBILITIES OF NEW TECHNOLOGIES

In order to be able to obtain depth of information, detailed digital data on the desired target, new technologies that render increasingly detailed information on the given targets become indispensable. These technologies include hyperspectral and multispectral imaging.

The classification of hyperspectral data by using statistical pattern recognition methods requires a lot of processing time. Image channels of the data are strongly correlated with each other. The classification and recognition of images requires algorithms of correct type. Hyperspectral images are produced by imaging spectrometers. Remote imaging has been utilized for scanning Earth and planetary surfaces. Typically, spectrometers are able to perform spectral measurements of bands, typically at least from 0.4 to 2.4 micrometers. The range represents visible through middle infrared wavelength ranges. Remote imagers in turn are designed to focus and measure the light reflects from many adjacent areas on the Earth's surface. The principle of spectrometer is presented in Figure 12.

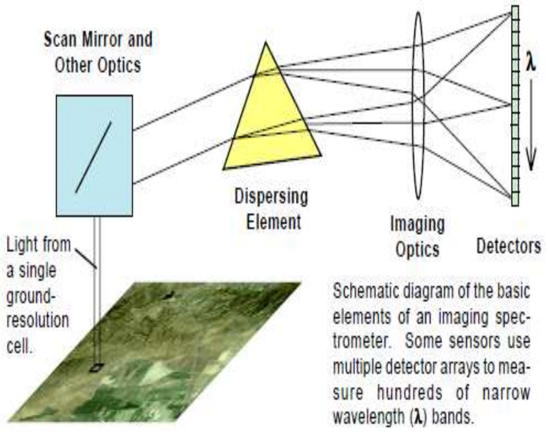

Figure 12. Functionality of an imaging spectrometer [40].

To interpret the scanned images, it is vital to understand spectral reflectance. As indicated in Figure 13, vegetation has higher reflectance in the near infrared range and lower reflectance of red light than soil [40].

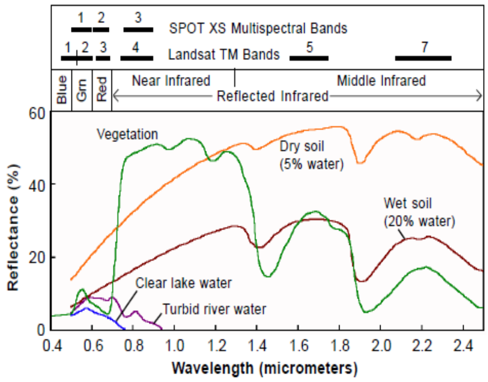

Figure 13. Representative spectral reflectance curves for several surface materials over the determined spectral range of visible light to reflected infrared [40].

Spectral libraries are important for they provide a source of reference spectra that can assist in the process of interpreting hyperspectral images. Imaging sensor converts detected radiance in each wavelength channel to an electric signal, which is then scaled and quantized into discrete integer values that represent encoded radiance values [40].

There are different strategies for image analysis. To interpret the collected data remains a challenge. Finding appropriate tools and approaches for visualizing and analyzing the essential information in a hyperspectral scene remains an area of active and constant research. Various countries and organizations have studied different approaches to solve the appropriate number of bands and wavelength ranges in order to improve the performance of spectrometers. The following Table II features the names of different types of sensors, organizations, number of bands used and wavelength ranges that have been identified.

TABLE II. A SAMPLE OF RESEARCH AND COMMERCIAL IMAGING SPECTROMETERS

A Sample of Research and Commercial Imaging Spectrometers

Sensor	Organization	Country	Number of Bands	Wavelength Range (µm)
AVIRIS	NASA	United States	224	0.4 - 2.5
AISA	Spectral Imaging Ltd.	Finland	286	0.45 - 0.9
CASI	Itres Research	Canada	288	0.43 - 0.87
DAIS 2115	GER Corp.	United States	211	0.4 - 12.0
HYMAP	Integrated Spectronics Pty Ltd	Australia	128	0.4 - 2.45
PROBE-1	Earth Search Sciences Inc.	United States	128	0.4 - 2.45

Hyperspectral image is comprised of several layers. Each layer contains data in certain wavelength. This is depicted in Figure 14.

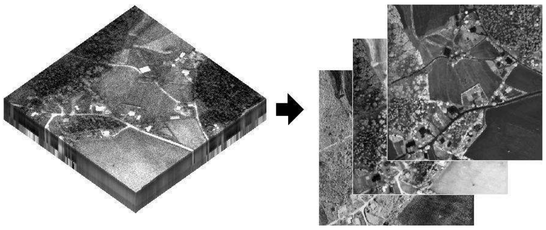

Figure 14. Hyperspectral image comprises several gray scale images that depict the same are in different wavelengths. [41].

Figure 15 features an image, in which steel rooftops are visible in white. The white color is visible in the process of interpreting the visual images provided by the sensors.

Figure 15. Steel roofs of buildings seen in white color [41].

One of the techniques used in UASs, laser scanning involves a scanning sensor transmitting thousands of pulses towards the target area (for example, terrain). The reflected echoes of pulses are then measured. Interpreting the collected images requires automatic classifiers. They search for artificial objects from the gathered data. In the future full waveform scanners are expected to produce more precise images from the scanned areas.

In thermal imaging sensor packages now weigh only 120 grams. The size and energy consumption of commercially produced sensors have decreased.

As indicated in [42], miniature size UASs, weighing few kilograms, equipped with payloads of hundreds of grams, are capable of performing reconnaissance operations performed during a short period of time. The typical Spatial Resolution (MS) is from one to twenty centimeters, when the fight-altitude remains below 500 meters as described in [42].

In practice, when two images, which have been taken from an identical area in a different time slot, are closely compared, it becomes possible to identify the changes. In doing so, changes surface concerning vehicles, pieces of artillery units, troops, and man-made bridges in the area of interest.

XI. DISCUSSION

Although there are similarities between the military's operational requirements and those of the civilian UAS industry, standardization is still very much lacking. Yet, it is standardization that is required between the military settings and civilian UAS markets. This is because the equipment needs to be compatible and interoperable and used for data collecting jointly if necessary. Unless there are set standards, end-users of technology cannot benefit from the development of synthetic vision systems, sensors, flight hardware, advanced materials and robotic systems as none of these would be affordable.

As for the seminal terminology, definitions of UAS and UAV can be found in [43] and [44]. Obviously, academia and industry continue to affect the evolution of the terminology used. Also, when dealing with organizing services among different entities, Service Oriented Architecture is an important issue. As indicated in [45], SOA fosters loose coupling of software assets, reuse of software components, acceleration of time to market, and reduction of organizational spending. The object is to benefit from the data collected with the best solutions available to increase the operational performance in accessing services, and lastly, to increase the speed and safety of operations executed. .

The data produced by various multi-sensors can be utilized in the data refinery process to ease the recognition and identification process. This can be done with the assistance of data fusion processes by resorting to computer-programs designed for these data fusion processes [33]. In fact, when using the KNearest-Neighbour (KNN) algorithm, approximately 80 % of unknown target samples can be recognized correctly, when the known target classification accuracy remains above 95 %. This enables the use of the ATR and the Automatic Target Cuer (ATC) [33].

As presented in publications [1], [33], the size and type of sensors have dramatically improved during past years. Sensors can be embedded inside artillery munitions or dispersed from aircraft. In some cases, helicopters can act as mother ships containing from tens to hundreds of small UASs and transport and drop them in designated areas for data accruing purposes.

When the UASs are successfully utilized in the different phases in a dismounted combat attack, the results can be optimally utilized. These gained results can be identified and evaluated in relation to the different stages of the process of a dismounted company attack. When the need of a requested service is identified, automated systems assist to fulfil the need of any type (need of data, resupply, firepower, evacuation).

UASs can be used for collecting updated and existing data and serving in the role of a radio transmission relay-link, as a flying hub-station and in assessing the impact of artillery fire. Using swarms of UASs enables quick, reliable and effective data collecting from a specified area. Furthermore, when UASs function as the communication link, the chain of command and control remains secure as regards communication.

By exploiting the data accessed by means of using UASs it is possible to enhance a dismounted military operation: readjusting the direction and action of combat units and increasing their speed. The communication between UASs and ground base-stations is encrypted. This ensures that the data collected and communication transmitted remain intact and coherent. UASs may fly via automated waypoints or serve as fighter-operated systems. UASs can be designed to be disposable, self-destroyable, once their task has been completed, or in case of malfunction, or if encountered by enemy. The use of SEMs becomes applicable in cases when the weather conditions are challenging, for example, the wind speed exceeds ten meters per second, or if data concerning a target must be rapidly accessed.

Compared to traditional WSN-systems, WPSN allows for improved security protocol in the communication between UASs and sensors. Data collecting systems gather raw data on battle space phenomena, for example, troop movements and action. These raw data feed the MDMP and facilitate speeding up the decision making. Using mathematical models and –programs produces improved SA and COP, compared to non-automatized human decision making performance. The improved SA and COP allow for significant increase in efficiency as regards planning and implementing the tactical use of destructive fire power.

As the raw data collected by UASs are already in electronic form, SOA can be utilized in planning, distributing and optimizing resources: evacuation, supplies, use of artillery fire. When the described systems for data collecting, analyzing, and communicating function as planned, it becomes possible to carry out an automated, computer-assisted attack as described in Figure 16. Utilizing FSO communication links fosters reliable, secure and coherent communication in command and control processes.

If and when all the accrued data can be properly processed and analyzed in MDMP with the assistance of SOA, the performance of troops can result in an automated dismounted company attack as depicted in Figure 16.

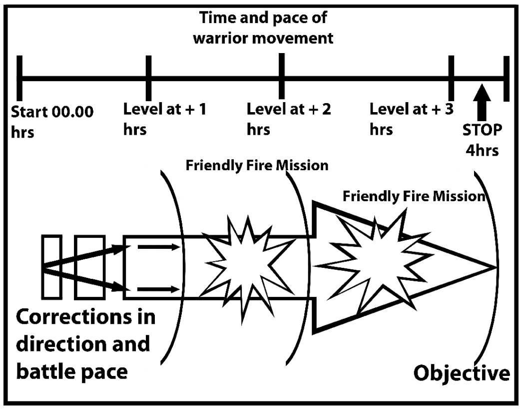

Figure 16. An automated attack operation. [1]

Figure 16 aims to visualize the goal of commanding military troops with the assistance of a computerized Artificial Intelligence (AI). The final commands for the military units to move and execute are given by a human commander, not by a machine. UASs can be seen as tools in monitoring and assisting in an operation when re-adjusting its pace: If the pace of the units or an individual soldier is too slow, the data transmitted by UASs is utilized to fine-tune the speed and direction of the operating troops. The SA data acquired by means of UASs must be used in taking the initiative and translating it into success in battle and eventually meeting the set objectives of the given military operation.

As indicated in Figure 16 that features an automated military attack, similarly it is possible to control and command a search and rescue operation in a civilian setting, for example in a traffic crash. In other words, the executed operation is automated and sequenced. The use of mathematical classifiers is based on computational power and effective algorithms. The effective algorithms are utilizable both in military and civilian environments in that they do not separate environment-specific factors per se but rather merely calculate the values inserted in the algorithms regardless of the environment in question.

XII. Conclusions

This paper examined how to utilize the real-time data collecting ability provided by UASs in order to improve the performance of a military performer and a civilian entity. This would require also standardizing the UASs to benefit both entities. The approach adopted is an idea-stage examination and as such aims to provide grounds for further discussion.

From a civilian perspective, the use of UAVs offers more cost-effective operational monitoring and management of natural resources. In flying low and slow and being comparatively affordable, UASs provide scientists with new opportunities for large scale appropriate measurement of ecological phenomena. This speeds up data gathering and saves natural resources in terms of energy consumption (aviation petroleum). The use of UASs does not disturb the balance of nature (animals, vegetation, birds migrating) more than using human-labor intense data gathering methods. From a military viewpoint, this paper relies on benefitting from the use of UASs as part of a dismounted company attack [1]. When doing so, it also points out the necessity of rapid data collection to support the fast MDMP.

According to the studies covered, it is important to continue doing research to improve the capabilities of data accruing with the assistance of UASs of various types. The variety and versatility of UASs continue to increase with UASs equipped with octo-rotors for superior maneuverability and stability as well as vertical take-off and landing. UASs are equipped with several types of sensor-packages depending on the data to be accrued. Also, the prevailing circumstances, such as mission duration and weather conditions, affect the equipping of UASs with bespoke sensor packages.

UASs are capable of producing high quality of data especially when platforms operate with low speed and in low altitude. Especially search and rescue missions benefit from mission effectiveness of the sensor and scanning systems, when sensors have enough time to monitor the areas beneath.

The UASs have to be able to communicate constantly with the base-station, and network reliability has to be ensured. The significance of connectivity presupposes that UASs must utilize suitable and reliable communication means and frequencies. Printed antennas have proved their efficiency in the frequency of 2.4 GHz ISM band. Embedded antennas provide several advantages for UASs, including reduced weight, lower manufacturing costs and lower drag.

The utilization and performance of UASs can be seen as data collectors in the battlespace. Sensors embedded into the UASs used can produce different types of data from the designated area. UASs can be deployed in most weather conditions and immediately when required, as there are no latency times. The data collected by UASs are then transmitted to the command posts. The collected real-time data remain critical for the MDMP. The data accrued must be in a pre-defined digitized form, which is applicable in digitized decision making systems exploited in the battlespace. The level and quality of SA continues to be critical at the dismounted close combat soldier level, whilst the level of COP plays an important role in command posts, where operations are planned, commanded and controlled.

Laser scanning and hyperspectral imaging offer new plausible means to accrue data from the battlespace. However, as these are technologies in-progress, uncertainty must be accepted.

The data for the MDMP are collected by using various types of sensors embedded into UASs and SEMs. The key issue is the speed of deploying the sensor package to the area. The prevailing combat situation in the battlespace determines the selecting of the type of UAS and sensor package embedded. The data accrued must be in a digitized form applicable in the software environment used. SOA can be used in re-organizing troops and allocating resources.

The ultimate goal of a dismounted company attack is to execute the mission with the resources allocated and to obtain the set objective. This asks for sustaining timely performance with a minimal number of casualties, decreased instances of fratricide and with the least possible amount of collateral damage. The objective is difficult to obtain, when relying on soldiers prone to erring. However, operational performance can be improved if the data collected by means of UASs are reliable and timely and can be adopted in active use to facilitate decision making. The possibility to use updated and analyzed data is vital for operations' success, especially in operations executed at a low operational level, such as a dismounted company attack. The utilization of these said data for decision making purposes may result in increased individual and collective performance capability in the executing of operations. With improved levels of SA and COP, operational security may be sustained.

When computers act as assisting tools both in the MDMP and its civilian equivalent offering suggestions as commands to the commander of attacking troops or, say, the staff in a search and rescue mission, the commander either approves or rejects the suggested commands. Thus, the role of a human decision maker remains critical in the chain of command.

XIII. Future Work

Because Situational Awareness data remain vital in successful military and civilian operations, the reliable data must be gathered with all the possible means available. This applies to civilian cases of success as well. Attention must be paid to planning the utilization of UASs together with accounting for the operational security issues concerning using software and hardware in the battlespace and in, for example, civilian rescue operations.

Future work must be focused on system reliability and ease of use of selected tools to improve COP and SA in both civilian and military environments.

The usability of UASs to create a functional communication network requires field testing in combat exercise settings prior to any operational use. UASs have to be remotely destroyable both physically and digitally. The capability of UASs to self-destroy when malfunctioning or having been shot down must be tested. Other identified challenges are related to maintaining an adequate level of constant energy flow and protecting against violations caused by electronic warfare.

The use of SOA in assisting the MDMP has to be studied in combat exercise settings as well in order to gain realistic and relevant data on human commanders evaluating COAs when planning a dismounted company attack.

It is impossible to interpret digitized data without appropriate and suitable algorithms. Therefore, calculation power is needed to improve the performance of MDMP and the utilization of SOA. When appropriate solutions are designed to meet these challenges, the planning and execution capability of both military and civilian operations may significantly increase.

Obviously, this involves implementing technologies so that they conform to the requirements set by the given usage environment. Data gathering tools and mathematical algorithms operate on the same principles whether the operational environment is a military or civilian one. The key is to allow for reliable data gathering in all circumstances complemented by reliable data analyzing and utilizing as part of digitalized decision making. Prior to making decisions the decision maker needs to have timely and secure access to the most recent Situational Awareness concerning the Area of Interest. This may then optimize operational success and eventually bring about the desired end outcome.

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