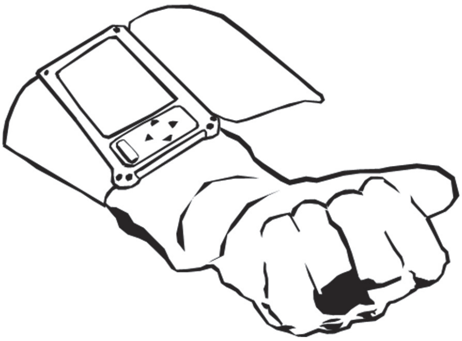
IMPROVING THE PERFORMANCE OF A DISMOUNTED FUTURE FORCE WARRIOR BY MEANS OF C^4I^2SR

Tapio Saarelainen



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With appreciation In Lappeenranta by Lake Saimaa

March 2013
Tapio Saarelainen

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ABSTRACT

This thesis comprises seven peer-reviewed articles and examines systems and applications suitable for increasing Future Force Warrior performance, minimizing collateral damage, improving situational awareness and Common Operational Picture. Based on a literature study, missing functionalities of Future Force Warrior were identified and new ideas, concepts and solutions were created as part of early stages of Systems of Systems creation. These introduced ideas have not yet been implemented or tested in combat and for this reason benefit analyses are excluded.

The main results of this thesis include the following:

A new networking concept, Wireless Polling Sensor Network, which is a swarm of a few Unmanned Aerial Vehicles forming an ad-hoc network and polling a large number of fixed sensor nodes. The system is more robust in a military environment than traditional Wireless Sensor Networks.

A Business Process approach to Service Oriented Architecture in a tactical setting is a concept for scheduling and sharing limited resources. New components to military Service Oriented Architecture have been introduced in the thesis.

Other results of the thesis include an investigation of the use of Free Space Optics in tactical communications, a proposal for tracking neutral forces, a system for upgrading simple collaboration tools for command, control and collaboration purposes, a three-level hierarchy of Future Force Warrior, and methods for reducing incidents of fratricide.

Keywords: Future Force Warrior, Wireless Polling Sensor Network, Service Oriented Architecture, Business Process, Situational Awareness, Command, Control, Communications, Computers, Intelligence, Information, Surveillance and Reconnaissance.

ATTACHED PUBLICATIONS AND THE AUTHOR'S CONTRIBUTION

P1. Tapio Saarelainen, White Force Tracking, Journal of Communications and Computer, vol 9, Number 1, January 2012, David Publishing Company, ISSN 1548-7709 (print) ISSN 1930-1553 (online), pp. 113–121.
This article is an individual work by the author.

P2. Tapio Saarelainen and Jorma Jormakka, Computer-Aided Warriors for Future Battlefields, The 9th European Conference on Information Warfare and Security ECIW2009, Lisbon, 6–7 July, 2009, Portugal, pp. 224–233.
This article was written by the author based on ideas suggested by Jorma Jormakka.

P3. Tapio Saarelainen and Jorma Jormakka, Interfacing Collaboration and Command Tools for Crises Management Military Command and Control Systems, International Journal of Electronic security and Digital Forensics, vol 3, No. 3, 2010, pp. 249–264.
This article was written by the author. Jorma Jormakka created the SDL-diagram.

P4. Tapio Saarelainen, Free Space Optics in the use of the Future Force Warriors, Journal of Communications and Computer, vol 9, Number 2, February 2012, David Publishing Company, ISSN 1548-7709 (print) ISSN 1930-1553 (online) pp. 123–133.
This article is an individual work by the author.

P5. Tapio Saarelainen, Jussi Timonen, Tactical Management in near real-time Systems, IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support, (CogSIMA2011), Miami Beach, Florida, 22.–25.2.2011, U.S.A.
This article was co-written with Jussi Timonen based on ideas suggested by the author.

P6. Tapio Saarelainen, Enhancing SA by Means of Combat-ID to Minimize Fratricide and Collateral Damage in the Theatre, The Sixth International Conference on Digital Telecommunications, (ICDT2011), Budapest, 17.–22.4.2011, Hungary. The Best Paper Award.
This article is an individual work by the author.

P7. Jorma Jormakka and Tapio Saarelainen, UAV-based Sensor Networks for Future Force Warriors, International Journal On Advances in Telecommunications, vol 4, numbers 1 and 2, 2011, ISSN: 1942-2601, pp. 58–71.
This article was written by the author. Because Jorma Jormakka created the One-Time Pad, his name appears first.

LIST OF ABBREVIATIONS

AAR	After Action Report
BC	Battalion Commander
BFT	Blue Force Tracking
BML	Battle Management Language
BP	Business Process
BSS	Battlefield Secure Scheduler
BW	Basic Warrior
CID	Combat Identification
CM	Crises Management
CME	Crises Management Environment
COP	Common Operational Picture
COTS	Commercial Off-The-Shelf
C^2	Command and Control
C^2IS	Command and Control Information Systems
C^4I^2SR	Command, Control, Communications, Computer, Intelligence, Information, Surveillance and Reconnaissance
DBH	Dynamic Battlefield Hierarchy
DIDEA	Detect, Identify, Decide, Engage and Assess
DRM	Dead Reckoning Module
DSU	Dynamic Schedule Update
FFW	Future Force Warrior
FSO	Free Space Optics, Fire Support Order
GOTS	Government Off-The-Shelf
GPS	Global Positioning System
GUI	Graphical User Interface
ID	Identification
LAN	Local Area Network
MANET	Mobile Ad Hoc Network
ME	Military Environment
MOOTHW	Military Operations Other Than War
MOUT	Military Operations in Urban Terrain
MOTS	Military Off-The-Shelf
MSOA	Military Service Oriented Architecture
NCO	Network Centric Operations
NCW	Net Centric Warfare
NEC	Network Enabled Capabilities
NED	Network Enabled Defence
OTP	One –Time Pad
PC	Personal Computer
PCIE	Peripheral Component Interconnect Express
PEO	Peace Enforcing Operations
PDA	Personal Digital Assistant

POI	Point Of Interest
P2P	Peer to Peer
PSS	Pre Shared Scheduler
QoS	Quality of Service
RBW	Readiness Brigade Warrior
RF	Radio Frequency
RFID	Radio Frequency Identification
RM	Resource Manager
ROE	Rules Of Engagement
SA	Situational Awareness
SCPA	Self-Calibrating Pseudolite Array
SDL	Specification and Description Language
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SoS	System of Systems
SSA	Shared Situational Awareness
SW	Special Warrior
UAV	Unmanned Aerial Vehicle
UG	User Group
UGV	Unmanned Ground Vehicle
UV	Unmanned Vehicle
WAN	Wide Area Network
WF	White Force
WFT	White Force Tracking
WPSN	Wireless Polling Sensor Network
WS	Web Service
WSN	Wireless Sensor Network
XML	Extensible Markup Language

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1. DEFINITIONS

The list of definitions comprises the used terms. To aid the reading of the compendium, each definition also reoccurs in the running text when the term in question appears for the first time.

Battlespace For the purposes of this study, battlespace is defined as the overall environment in which military operations are executed comprehending sea, land, air, and the electromagnetic spectrum. The term battlespace replaces the term battlefield, as the latter is understood to involve the land-warfare component, whereas the term battlespace comprises the environment that exhaustively covers the area in which operations are being executed. The composition of a land-component includes different types of perimeters, such as forests, deserts, jungle, mountains, rural areas, towns, cities and built-up areas in all their forms. A battlespace is also the environment in which sensors, sensor networks and communication networks exist.

Blue Force refers to soldiers of own troops or soldiers of allied troops. Warriors on the same side of an operation compose the Blue Force. Also Unmanned Vehicles of own troops are entities of the Blue Force.

Blue Force Tracking (BFT) Blue Force Tracking is a location system used in military and crises management operations to locate and identify friendly forces in a battlespace. Blue Force Tracking is composed of various sets of tracking and location devices that can be combined to respond to the operational needs. The main objective of these devices is to track and locate a person or vehicle carrying these devices as a friendly force member. The use of these systems aims to reduce fratricide and minimize casualties of own troops by identifyig persons of friendly forces to avoid engaging against an identified person.

Business Process (BP).
Business Process is a chain of events in which each former process marks a starting point to the next process and this cycle evolves and moves on. Business Process represents a usual civilian process concerning how business processes are carried out. BP is modeled as a selection of services provided by Service Oriented Architecture. BPs are operated by an inbuilt process engine.

Command and Control (C^2) refer to the processes related to the operating and commanding of military troops and units in a battlespace. The C^2-processes are performed at all military levels when missions are planned, executed and analyzed.

Common Operational Picture (COP) stands for an overall understanding of the prevailing situation in a battlespace. Common Operational Picture can be presented on the screen of a computer or a digital device, as well as by using markers and conventional maps. Common Operational Picture features elements such as individuals of friendly forces, neutral entities and the adversary, presented by symbols of various types.

Crises Management Environment (CME) is an environment encountered in peace supporting operations and peace enforcing operations including society rebuilding efforts and other types of activities that are part of Military Operations Other Than War (MOOTHW). These operations typically include friendly forces, neutral forces and an adversary (red force). The entities involved can execute operations parallel to military operations. The entities concerned involve international non-governmental organizations, for instance, the Red Cross or Crescent, and the World Health Organization (WHO).

C^4I^2SR consists of Command, Control, Communications, Computers, Intelligence, Information, Surveillance and Reconnaissance. This composition forms tools for accruing, forwarding and analyzing data to produce necessary information. This information is used to create Common Operational Picture and enhance overall Situational Awareness.

Data fusion is used to analyze the data gathered from the battlespace. These data can be gathered by means of various types of sensors, data-bases and different actuators. Data fusion can be utilized in improving the performance and accuracy of various types of detection, tracking and surveillance systems as described in [13].

Military Environment (ME) comprises all the thinkable environments, in which military operations are to be executed on land, in the air, at sea, and in the electromagnetic spectrum. Examples of operations cover defensive operations, attack missions, operations in urban terrain and coastal operations. Less typical operations include rescue operations and search and destroy operations.

Network Enbled Capabilities comprise all the thinkable capabilities networks can offer. This means that decision entities and command and control elements become as knowledgeable as possibe. Actors and decision making entities are thus optimally connected. Sensors and shooters are tightly connected with decision makers.

Network Centric Warfare (NCW) considers the battlespace environment a distributed heterog- enous system, consisting of reactive and cognitive agents functioning in relation to environmental factors or Shared Situational Awareness towards the final objective. NCW translates into a System of Systems (SoS) comprising intelligence gathering sensors, command and control –systems that enable enhanced SA and target assessment. This combined with the ability to network well with informed geographically dispersed forces and informed technological changes in a battlespace allows developing new forms of operational behavior to ensure mission success.

Product-line warrior stands for a warrior whose production is carried out industrially on an assembly line with characteristics dependent on the warriors' set tasks and requirements. Product-line warriors include the categories of Basic Warrior, Readiness Brigade Warrior and Special Force Warrior.

Reconnaissance represents the military term for advancing beyond the area occupied by friendly forces to gain vital information of enemy forces or features of the environment for later analysis and/or dissemination. Examples of reconnaissance include patrolling by troops (military intelligence specialists), vessels of any type, manned/unmanned aircraft and satellites, or setting up covert observation posts to reconnoitre areas, vehicles, persons, and incidents.

Situational Awareness (SA) has been given an applicable definition in the Army Field Manual 1-02 [51] dating back to 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." SA comprises three levels: 1) perception, 2) comprehension and 3) projection. SA or lack of it remains a key factor in military operations and intelligence capabilities. 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.

Shared Situational Awareness (SSA) can be understood as distributed situational awareness and SSA data collected by many entities. Situational awareness data collected can be forwarded to command posts or data-mining centers for analysis and distribution purposes. With the assistance of Service Oriented Architecture (SOA) and selected data-mining algorithms, the collected data can be analyzed and processed for further distributing purposes to foster mission success. Shared Situational Awarenes has a vital role in Network Centric Warfare.

Service Oriented Architecture (SOA) represents a means to operate and orchestrate processes and services effectively to achieve the goals set for operations. SOA prepares a granular platform of independent services on a networked infrastructure, utilizing a common language together with standard protocols for negotiations improving overall availability, utilization and flexibility of the available services. In this present study Service Oriented Architecture is strongly related to SA and the processes of managing resources and services.

Surveillance equals a data collection method and involves monitoring the movements or affairs of a phenomenon, person or vehicle or aerial changes. Surveillance is systematic on-going collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that action can be taken. Surveillance can also be focused on computers. Computer surveillance can involve accessing or "reading" the storage mechanism of a computer, or monitoring a person's operation of a computer. To summarize, surveillance means data collection for operational purposes.

Tracking involves the observing of persons or objects on the move and supplying a timely ordered sequence of respective location data to a model which is, for instance, able to serve in depicting the motion on a display.

2. INTRODUCTION

This thesis introduces some possibilities to improve the performance of a dismounted Future Force Warrior (FFW). For the purposes of this study, a dismounted Future Force Warrior describes a warrior who fights dismounted on the ground rather than mounted from a vehicle. The means examined include communication devices attached to warrior gear. The term gear refers to the weaponry and versatile communication systems which facilitate communicating in a battlespace.

For the purposes of this study, battlespace is defined as the overall environment in which military operations are executed comprehending sea, land, air, and the electromagnetic spectrum. The term battlespace replaces the term battlefield, as the latter is understood to involve the land-warfare component, whereas the term battlespace comprises the environment that exhaustively covers the area in which operations are being executed. The composition of a land-component includes different types of perimeters, such as forests, deserts, jungle, mountains, rural areas, towns, cities and built-up areas in all their forms. A battlespace is also the environment in which sensors, sensor networks and communication networks exist.

This study focuses on the early stages of a System of Systems developing process. This means generating ideas and possibly prototyping them. The dismounted FFW represents a combination of a warrior and a system platform for several integrated and embedded digital systems. This study examines the means to enhance the situational awareness level of an individual warrior and also how to improve the overall Common Operational Picture (COP) of a given military organization.

Common Operational Picture (COP) stands for an overall understanding of the prevailing situation in a battlespace. Common Operational Picture can be presented on the screen of a computer or a digital device, as well as by using markers and conventional maps. Common Operational Picture features elements such as individuals of friendly forces, neutral entities and the adversary, presented by symbols of various types.

One of the most important issues concerning the development of an FFW involves minimizing the incidents of fratricide. The ability to minimize fratricide, reduce collateral damage, and increase situational awareness enhances the probability of reaching the set objectives in military operations.

As regards the total mass of warrior gear in FFW-systems, a reasonable maximum of 30 kilograms represents approximately one third of the average mass of a 90-kilogram dismounted

FFW. The long-term goal in FFW -programs is to bring down the total mass of the warrior gear down to 20 kilograms. This can only be achieved by carefully selecting the gear required. In the future, the FFWs can be vieved as product-line warriors.

The notion of a product-line warrior stands for a warrior whose production is carried out industrially on an assembly line with characteristics dependent on the warriors' set tasks and requirements. Product-line warriors include the categories of Basic Warrior, Readiness Brigade Warrior and Special Force Warrior.

2.1 Research problem and research questions

The main research problem in this thesis is how to improve the overall performance of a dismounted FFW by means of Command, Control, Communications, Computer, Intelligence, Information, Surveillance and Reconnaissance (C^4I^2SR).

C^4I^2SR consists of Command, Control, Communications, Computers, Intelligence, Information, Surveillance and Reconnaissance. This composition forms tools for accruing, forwarding and analyzing data to produce necessary information. This information is used to create Common Operational Picture and enhance overall Situational Awareness.

The study also examines the possibilities to improve warrior-level Situational Awareness and commanders' Common Operational Picture. Domain-specific terms, such as, Command, Control, Communications, Computer, Intelligence, Information, Surveillance and Reconnaissance services, are in a central role in this study. This thesis attempts to outline possible communication and sensor network tools for battlespace use.

Surveillance equals a data collection method and involves monitoring the movements or affairs of a phenomenon, person or vehicle or aerial changes. Surveillance is systematic ongoing collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that action can be taken. Surveillance can also be focused on computers. Computer surveillance can involve accessing or "reading" the storage mechanism of a computer, or monitoring a person's operation of a computer. To summarize, surveillance means data collection for operational purposes.

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Situational Awareness (SA) comprises three levels: 1) perception, 2) comprehension and 3) projection. SA or lack of it remains a key factor in military operations and intelligence capabilities. 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.

Service Oriented Architecture is currently seen as a promising technology in military operations. The execution of military tasks with the assistance of Service Oriented Architecture is viewed as a possible execution enabler and plausible force multiplier.

Service Oriented Architecture (SOA) represents a means to operate and orchestrate processes and services effectively to achieve the goals set for operations. SOA prepares a granular platform of independent services on a networked infrastructure, utilizing a common language together with standard protocols for negotiations improving overall availability, utilization and flexibility of the available services. In this present study Service Oriented Architecture is strongly related to SA and the processes of managing resources and services.

This raises the question if an FFW can also benefit from Service Oriented Architecture services and how Service Oriented Architecture could enhance warrior performance.

Technical solutions based on Commercial Off-The-Shelf -technology offers tempting possibilities applicable also in crises management operations. This is important because communication and location requirements are constantly in a central role in military operations. In the currently prevailing world-wide recession, it remains relevant to examine how FFWs can benefit from Commercial Off-The-Shelf –technology.

The research questions of this thesis are:

1) What could be a suitable sensor network tool for current operational situations?
2) How can Service Oriented Architecture be used in military settings to improve warrior performance?
3) How can militaries benefit from new communication technology in crises management operations?
4) Which new concepts can be developed to aid in minimizing incidents of fratricide and collateral damage?

2.2 Main Results

The seven papers included in this thesis examine the overall performance of a dismounted FFW. The main results of this thesis are as follows:

The Wireless Polling Sensor Network (WPSN) concept. While Wireless Sensor Networks (WSNs) have been used for a long time, they have certain draw-backs: multi-hop transmission fails when nodes are destroyed in military environments, battery lifetime poses limitations, and security challences have not been solved. A Wireless Polling Sensor Network (WPSN) has advantages in all of these areas compared to other proposed solutions. A WPSN comprises a small mobile ad hoc network of UAVs and a high number of fixed ground-based sensors, which are periodically polled by UAVs. This concept suits well to road bomb detection, to guiding precision munitions to a target in an indoors location.

The Business Process approach to Military Service Oriented Architecture (MSOA). This means treating military operations as Business Processes, chains of actions to be performed in a given sequence. The future vision in the military Business Process approach involves a computer-directed warrior. Usually SOA services can be simultaneously used by any Business Processes, but in military operations services represent limited resources that must to be scheduled. Therefore the author developed a new general purpose SOA-component, the military Resource Manager, to facilitate the process of managing the available resources. Additional new concepts for the Business Process approach include a Dynamic Battlefield Hierarchy and Battlefield Secure Scheduler.

The thesis also contains a number of other results.

White Force Tracking (WFT). This means tracking the locations of civilians in a battlespace. While the need to reduce collateral damage has always been acknowledged, systems for tracking the White Force (WF) have not been considered earlier.

Command, Control and Collaboration systems. This is a new concept that upgrades present collaboration-tools to military-level Command, Control and Collaboration systems. Addressed issues deal with trust and security when issuing and receiving commands from external players such as civilian authorities or members of crises management organizations.

Application of Free Space Optics in tactical communications. Radio-spectrum imposes serious limitations on bandwidth. As an FFW has a laser-designator in his gear, the author investigated Free Space Optics (FSO) transmission as a potential technology for high-bit rate data transmission, for example, when transmitting pictures to enhance Situational Awareness.

Three-level hierachy of a dismounted FFW. The hierarchy comprises Basic Warrior (BW), Readiness Brigade Warrior (RBW), and Special Warrior (SW). The concept defines the gear of each warrior type, their tasks, and performance capabilities.

2.3 Scope and Structural Outline

The thesis attempts to find possible solutions for improving the overall capabilities of a dismounted FFW. The performance of a dismounted FFW can be increased by selected means of C^4I^2SR–tools and applications. This idea involves viewing the FFW concept as an SoS and the product-line warriors' electronic skeleton as a system platform. This allows examining the utilization of the existing Commercial Off-The-Shelf (COTS) –based applications and possible technologies, such as Wireless Polling Sensor Network. The thesis aims to generate plausible ideas for the creation process of a dismounted FFW as an SoS.

When a military operation can be streamlined as a process similar to a Business Process, several maneuvres can be simplified and modeled. For this reason, this study features in a key role Service Oriented Architecture, which the author has supplemented by tools such as the military Resource Manager, a Scheduler, Dynamic Battlefield Hierarchy (DBH) and Battlefield Secure Scheduler (BSS).

This publication begins by covering key definitions (Chapter 1) and then proceeds to the introduction (Chapter 2) complemented by research methods (Chapter 3). This is followed by a review of FFW systems (Chapter 4) after which the dismounted FFW concept is discussed (Chapter 5). Then the Business Process (Chapter 7) and battle management systems (Chapter 8) are discussed followed by a description of the papers produced (Chapter 8). Finally, the section on how to proceed (Chapter 9) precedes the conclusions drawn (Chapter 10).

The present study can be described as an evolving spiral, in which all the previously (cf. 2.1–2.3) described aspects have to be accounted for when idealizing and planning a dismounted FFW with improved capabilities. This spiral is depicted in Figure 1.

SOA	Service Oriented Architecture
RM	Resource Manager
FFW	Future Force Warrior
COP	Common Operational Picture
WPSN	Wireless Polling Sensor Network System
BP	Business Process
C^4I^2SR	Command, Control, Communications, Computer, Information, Intelligence, Surveillance and Reconnaissance

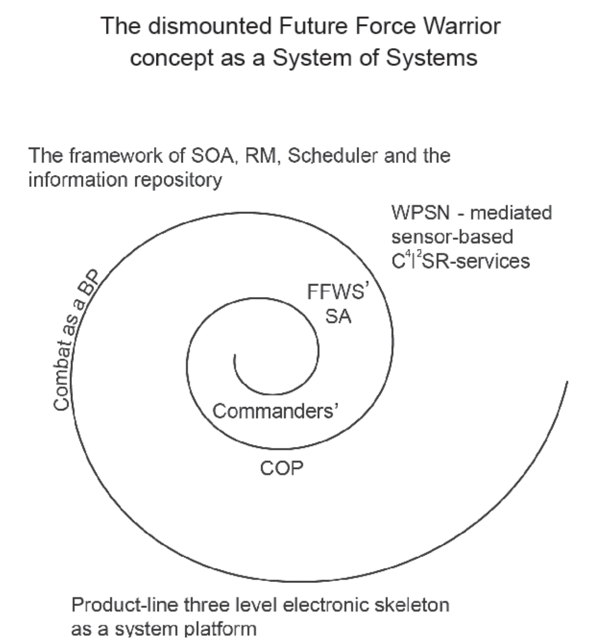

Figure 1. The Future Force Warrior concept as an SoS.

As visualized in Figure 1, the dismounted Future Force Warrior (FFW) -concept can be viewed as a System of Systems (SoS) which, first of all, comprises as its framework a military application of Service Oriented Architecture (MSOA) featuring the military Resource Manager (RM), a Scheduler, and the Information Repository, to facilitate the allocating of the limited resources available. Secondly, the product-line warriors' three-level electronic skeleton is viewed as a system platform in which the gear and training of FFWs vary depending on their tasks. Thirdly, combat is understood as a Business Process (BP) in which the Wireless Polling Sensor Network (WPSN) is utilized in mediating sensor-based C^4I^2SR-services in order to improve FFWs' Situational Awareness (SA) and provide data for creating an accurate Common Operational Picture (COP) – a necessity for Commanders to ensure their effective decision-making.

3. RESEARCH FRAMEWORK AND METHODS

The research method employed is the following. Based on a survey of warrior systems in Chapter 4, problems that have not yet been exhaustively solved have been identified. After having identified missing sub-systems, new solutions and concepts have been invented and designed at a conceptual level in the papers produced for this thesis.

The literature survey of Chapter 4 was done by collecting studies related to the concept of Future Force Warrior. Obviously, militaries continue preparing for operations and nations keep spending significantly in developing new warrior systems. Therefore it is not a simple task to find reliable and updated unclassified data on solutions and devices suitable for a dismounted FFW. The data collecting was carried out by examining scientific papers written on applicable technological issues. Scientific papers focusing on military issues were utilized in the process of generating ideas. This meant reviewing and examining a high number of papers. For the reasons just explained, this process has solely drawn from accessible unclassified and unrestricted literary sources.

The research method of, on the one hand, examining relevant existing papers, and on the other hand, generating ideas, was selected because it is suitable for an officer who wants to participate in the development process of new technologically informed FFW systems. An officer is somewhat aware of the practical side of the end-product, the obvious end-user needs, currently missing solutions and usability requirements. This officer's input occurs in an early development stage. The aim is to find technologies applicable to foster the overall capabilities of a dismounted FFW. The method for this equals generating ideas and drawing comparisons. Solutions are described at a conceptual level, and some are prototyped in a laboratory, but none are combat-proof.

Table 1 summarizes the identified problems found in the literature survey that are addressed in the papers produced by the author.

Paper	Identifying problems with missing solutions	New concepts and solutions
P1	Blue Force Tracking exists, but in crises management situations a high number of neutral personnel remain unlocated.	White Force Tracking System has been outlined.
P2	FFW –programs exist, but equipping all the warriors with the best gear is very expensive. Furthermore, how does a warrior benefit from a computer?	Three-tier warriors have been identified, and a new computer aided-warrior concept is introduced.
P3	Collaboration tools are currently capable of information sharing only. Activities of Non-Governmental Organizations present new challenges to military actors.	A Command, Control and Collaboration tool has been invented.
P4	Combat Net Radios have low bit rates. Crises management operations could benefit from transmitting images contributing to Situational Awareness.	A Laser Target Pointer can be used for Free Space Optics transmission.
P5	SOA is currently used for services rather than Business Processes. Battlefield management systems exist.	A Business Process approach to Service Oriented Architecture was applied in military tactical operations.
P6	Fratricide prevention systems are needed, but they are expensive.	Outlined practical alternatives for preventing incidents of fratricide.
P7	Wireless Sensor Networks exist, but feature some serious problems in military settings. New threats include roadsidebombs. One-Time Pads cannot be distributed.	A Wireless Polling Sensor Network concept has been implemented. One-Time Pad exchange protocol has been invented by Jorma Jormakka.

Table 1. Problems and solutions identified by the literature survey.

3.1 Criteria for selecting new technical systems

When selecting new technical systems for a dismounted FFW, the most important feature is performance. The overall troop performance is composed of the existing key elements available rather than the technologies or ideas described. Figure 2 depicts the key elements of overall performance capabilities; namely, troops, materiel, usage principles, infrastructure, support and integration of capabilities. These elements are used in militaries worldwide to define the general performance of nations' Defence Forces.

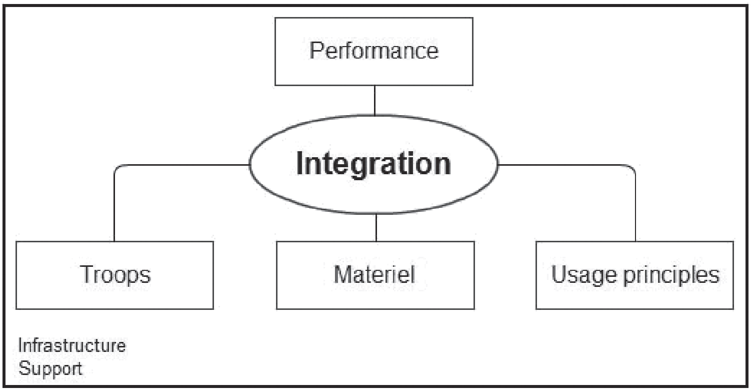

Figure 2. Key elements of overall performance capabilities.

Performance can be understood as an output of a described system.

Troops can be understood as the composition and structure of military troops located in an organization. The organization can be an Army as whole or a particular part of given military organization, for example, a Brigade.

Materiel comprises all the equipment used in operations (weapons, vehicles, ammunition, communication systems, medical supplies, etc.).

Usage principles are related to operational techniques, tactics, procedures, including the operational use of troops. Usage principles define the way in which troops are exploited in military operations.

Infrastructure is the composition of services and supply chains. Infrastructure means the composition of military and civilian infrastructures in a war-time setting.

Support can be understood as a capability to support operations.

Integration is understood as system integration. System integration is a process of linking together different services and actors to enable functioning as a coordinated whole. The integration of systems enables integrating computer networking systems and necessary military services required as Business Processes in a battlespace.

3.2 Contributions of the thesis to the Future Force Warrior concept

The following Figure 2 below indicates the placement of the published articles in relation to the FFW-concept. Apart from sporting task-level-dependent warrior gear and clothes, each dismounted FFW is subject to two sub-systems: Command, Control and Communications, and Situational Awareness, which are here considered separate.

Firstly, C^2–systems contain Command and Control, which here are SOA-based and Wireless Communication Systems. Command and Control (C^2) refers to the processes related to the operating and commanding of military troops and units in a battlespace. The C^2-processes are performed at all military levels when missions are planned, executed and analyzed.

Secondly, a Situational Awareness sub-system contains some independent mechanisms, such as fratricide prevention and SOA Services. In this solution depicted in Figure 3, sensor systems, identification systems and inter-working systems are realized as SOA services.

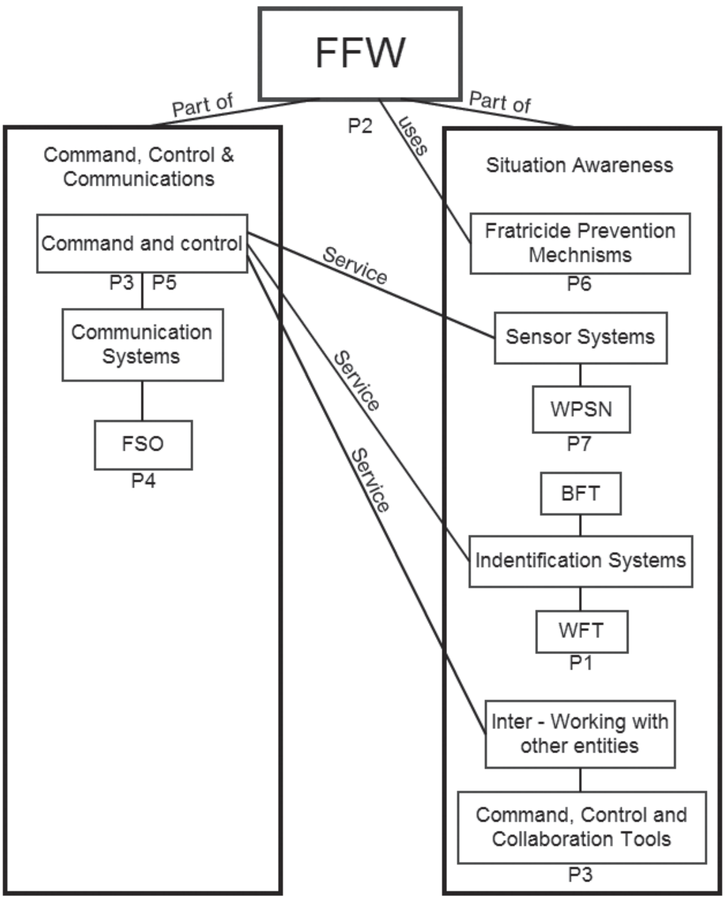

Figure 3. Contributions of the papers

3.3 Technical-constructive approach

The research method used in this thesis represents a technical-constructive method. It is part of a product development process offering new ideas and concepts utilizable when creating functioning C^4I^2SR and SA systems for a dismounted FFW. Generating ideas marks an early stage of a product development process and the results of this work should be seen as possible solution concepts applicable in a battlespaces of the future.

The evaluation and benefit analyses of the new concepts belong to later stages of the product development cycle and are thus omitted from this study. Detailed military requirements such as robustness, security, and logistics can be addressed only in a planning stage in which the given military entities have defined the actual set parameters necessary and carried out the required threat analyses.

The goal of the present study is then merely to create ideas based on innovative and publicly available Commercial Off-The-Shelf -technology. Therefore the actual functionality and operability of a dismounted FFW concept as an SoS can be credibly tested only in operations performed in an actual battlespace.

The method adopted for developing new solutions has equalled a modification of a think-tank -method. The solutions presented represent possible solutions when properly applied. Two types of approaches have been utilized in this process: the analysis of the presented system as part of a designated military application, or as part of a whole set of military applications. An example of the former approach is the solution capable of tracking impartial entities, White Force Tracking, see P1. An example of the latter one is the use of SOA in enhancing the optimization of existing resources, as introduced in P5. As described in P5, the method can be seen as a new solution to utilize SOA. With the assistance of SOA, a military commander can concentrate on commanding his or her automatically recovered chain of command. This study has attempted to contribute to improving overall situational awareness and common operational picture with SOA to support commanders' decision-making process. P7 examines improving overall performance of a dismounted FFW while accounting for C^4I^2SR-challences.

3.4 The characteristics of a product design process

In developing new technical solutions applicable, the Systems of Systems philosophy of product design has been followed. A dismounted FFW as a concept represents an SoS, a set of selected systems and sub-systems. The process of creating a dismounted FFW represents a process of product or systems design in which the following stages need to be taken into consideration: 1) decision making, 2) performance measures, 3) iteration, and 4) information management. Decision making in product design aims at creating a solution to an identified product design problem. Performance in this process is evaluated against the amount of resources available (time, human resources, cost-factors). Iteration involves performing similar activities at different points in the design process. It includes resolving the same product design problem multiple times. Information management is related to the data collected on the whole design process. Decisions are made on the basis of the data collected and analyzed.

The product design process comprised repeated iteration of three activities: analysis, synthesis and evaluation, processes similar to the one used in [142]. The analysis involved understanding the design problem and generating the requirements and specifications. The synthesis dealt with generating ideas and solutions by studying battlespace environments. The evaluation included assessing the design solutions against the requirements, specifications, which, as explaned earlier, remain theoretical as the actual information remains classified. More information about the SoS approach is offered in [48].

The analyses process of a product design process in its early stage may follow a specific approach, for example, axiomatic design, as introduced in [139] and functional analysis (or value engineering) introduced in [109] and [138]. In this thesis the analyzing process adopted has been an informal one.

4. REVIEW OF FFW-SYSTEMS

The following reviews current studies on FFW C^4I^2SR systems relevant in the context of this thesis. This chapter is organized as follows: Battle Management Systems (BMS) are introduced first, followed by SA, Crises Management (CM) contexts, and Net Centric Warfare (NCW), after which the significance of networks is discussed. Then we proceed to Free Space Optics, Unmanned Aerial Vehicles (UAVs), Tracking and Localization, Service Robots, SOA, and, lastly, very briefly point out some issues on FFW training and simulations.

As for the term FFW, an FFW represents a dismounted warrior who is supplied with the latest applicable technology. The purpose of improved gear and new technological devices is to enhance the overall performance of an FFW. This requires that the embedded systems feature computer-aided modularity and scalability. The equipment must be tailored to be rapidly replaceable in case broken, lost or malfunctioning in a battlespace.

The goal of this literature review was to locate missing sub-systems in FFW-systems. Findings of the literature survey were collected to Table 1.

4.1 Battle Management Systems (BMSs)

The C^2 capabilities necessary to units serving at battalion level and below are provided by Battle Management Systems (BMSs). Especially combat net radios can be seen as beneficial tools to support the goal of geographical based situational awareness. When several operational BMSs are integrated to gain the maximum amount of quantative and qualitative data for the purpose of analyses in the field of SoS-concepts, various robotic platforms can be utilized, as described in [72]. An SoS can be understood as large-scale concurrent and distributed systems consisting of complex, interoperable systems. This applies to an SoS composed of robotic systems, see [72].

As introduced in [41], BMSs draw from strong hierarchies and Hierarchical Communications Protocol (HCP). The C^2-communication systems are based on different levels of communication (structure creation and cell-center selection) in varying types of communication contexts (point-to-point communications, broadcast communications), as shown in [41]. Hierarchical Communications Protocol can be based on geographical routing that builds a virtual three-level infrastructure in a battlespace, see [41]. However, aligning SoS and HCP requirements remains a challenge. The ability to trace the requirements set for different levels and to obtain coherent models of C^2-systems were found to be the major benefits in using the architecture framework introduced in [63]. In [63] the key finding was that architecture framework supports the modeling of the operational system and the technical system.

The operational functions of BMSs are based on Battle Management Language (BML), which enables the advancements of IT-supported functions of BMSs as indicated in [126]. Battle management language is a language utilized in the command and control of troops and equipment in military operations. BML can be used in outlining Shared Situational Awareness (SSA) and in creating the common operational picture, see [126]. When using BML for military communications, automatically structured information can be transparently organized. BML can also be used between C^2-systems and simulation systems. In the storing process of all the information available, BML offers a means to accelerate the storing process as introduced in [126].

The functioning of Battle Management Systems can be enhanced by relying on decision support systems of military communication networks. Military communication networks are in an essential role in achieving information superiority in net centric warfare and information warfare as described in [35]. The intelligent decision support system framework is strongly linked to SoS and BMS. When these systems are merged, data mining systems may be significantly improved as well.

Command and Control Information Systems (C^2IS) are crucial in tactical planning and tactical communications networks, as discussed in [77], which are closely connected to network descriptions in an operational network simulation model's parameters. In joint operations the Multilateral Interoperability Program (MIP) was established to advocate successful and harmonized operational functions for peace-keeping forces, see [77]. Interoperability is to be achieved by Command and Control Information Exchange Data Model (C^2IEDM), which advocates the use of data bases. Moreover, joint command, control and consultation information exchange data model aims towards improved information sharing and data exchange and storage and retrieval systems used in multinational operations, see [77].

As shown in [110], the presented "Dynamic analysis of the Brigade Combat Team's C^2 architecture" can be seen as an example of one of the efforts enabling getting ahead of an adversary's decision cycle. This enhances the capability of army battle command systems to utilize the gathered information and provide exhaustive data for the base of a tactical operations centre, see [110]. This architecture is created to foster the military decision making process, see [124], along with the process of recognition primed decision making. In light of the continuing changes in operational environments and organizations, C^2-structures and suitable presentation methods of data combined with the military decision making process, recognition primed decision making and used networks must be secured to enable remaining aware of the actions and locations of own troops. Moreover, enemy courses of actions in maneuver-centric conventional operations are accompanied by a situation template that depicts the enemy courses of actions and blue force graphically on a screen, see [189].

4.2 Situational Awareness (SA)

Used in varying domains, such as air traffic control, aviation and military C^2, as discussed in [44], situational awareness comprises three identified levels: 1) perception, 2) comprehension and 3) projection, see [44]. SA or lack of it remains a key factor in military operations and in intelligence capabilities, especially in Web-Based Intelligence Networks, see [46]. Situational awareness is linked to dismounted battle command system, as discussed in [47], and to voice communications over Blue Force Tracking systems, see [32], which has become a critical capability for the military, as discussed in [27].

Blue Force refers to soldiers of own troops or soldiers of allied troops. Warriors on the same side of an operation compose the Blue Force. Also Unmanned Vehicles of own troops are entities of the Blue Force. Blue Force Tracking (BFT) Blue Force Tracking is a location system used in military and crises management operations to locate and identify friendly forces in battlespace. Blue Force Tracking is composed of various sets of tracking and location devices that can be combined to respond to the operational needs. The main objective of these devices is to track and locate a person or vehicle carrying these devices as a friendly force member. The use of these systems aims to reduce fratricide and minimize casualties of own troops by identifyig persons of friendly forces to avoid engaging against an identified person.

Blue Force Tracking was utilized during Operation Iraqi Freedom, see [27]. As described in [96], the tactical network systems are ad-hoc mobile communications that significantly contribute to an improved SA for BFT-systems. SA is strongly linked to the military decision making process in smaller operational units, such as platoons and squads. The company command support system is introduced in [124]. Tools to increase the overall SA are often seen as collaboration tools, whose goal is to increase Shared Situational Awareness, as discussed in [17]. This is also the case in technology-enabled non-face-to-face collaboration tools used while simultaneously providing near-real-time information in disaster situations, as described in [135].

Shared Situational Awareness (SSA) can be understood as distributed situational awareness and SSA data collected by many entities. Situational awareness data collected can be forwarded to command posts or data-mining centers for analysis and distribution purposes. With the assistance of Service Oriented Architecture (SOA) and selected data-mining algorithms, the collected data can be analyzed and processed for further distributing purposes to foster mission success. Shared Situational Awarenes has a vital role in Network Centric Warfare (NCW). NCW considers the battlespace environment a distributed heterogenous system, consisting of reactive and cognitive agents functioning in relation to environmental factors or Shared Situational Awareness towards the final objective. NCW translates into a System of Systems (SoS) comprising intelligence gathering sensors, command and control –systems that enable enhanced SA and target assessment. This combined with the ability to network well with informed geographically dispersed forces and informed technological changes in a battlespace allows developing new forms of operational behavior to aid in mission success.

Tools and concepts applied in Net Centric Warfare environments contribute to improving SA, see [150]. The end-state is to merge the data collected from a finite array of sensors and sources. Service Oriented Architecture and semantically aware systems are seen as enablers in the process of knowledge fusion, described in [31]. Predictive situational awareness benefits from the possibilities provided by the use of probabilistic ontologies for net-centric operation systems, as discussed in [31]. Predictive situational awareness applies a multi-disciplinary approach to solve the problem of predictive situational awareness within the domain of maritime operations, see [31].

The context of C^4I^2SR battlespace communications emphasizes the overall significance of the elements and phenomena related to SA as discussed in [150]. As systems, tactics, techniques, and procedures evolve, the aspects and terminology concerning SA drastically increase. Military decision making process is linked to collaborative SA in time-critical operational environments, especially military operations indoors where location data are essential, as described in [143], as well as to company command support systems, see [124], and, lastly, to team situation awareness perspective, as described in [140], as well as enemy courses of actions, as discussed in [145]. In time-critical operations fast decision making is inevitably based on inadequate information on the overall situation. Cognitive situation modeling and recognition situation management apply the management of complex dynamic systems, see [73]. Situation management is understood as a combination of components, such as 1) situational awareness and 2) situation calculus and situation control, see [73]. As indicated in [73], integrating the systems with real-time situation models can be seen a useful means for decision support systems in medical relief operations, see [15] and [73].

In the context of Network Centric Operations (NCO), innovative enhancement to military decision-making is desired to be able to facilitate the decision maker's perception, as described in [64], and processes and computational models are required in supporting high levels of Shared Situational Awareness enhancing decision-makers' perception, comprehension and projection of the underlying knowledge space requires adopting the recognition primed decision model, as discussed in [64].

The significance of SA is critical in Military Operations in Urban Terrain (MOUT). As described in [86], building clearing exercises posed challenges for training requirements set for special weapons assault teams. To support training for oncoming operations, the After Action Reports (AARs) can be supported by generating performance feedback tools built in SA-systems and testing these tools before the AAR-processes, as discussed in [86]. The study described in [115] can be used as an example to reach the goal for improved performance and reduced numbers of casualties. To sum up, the significance of SA is closely examined in all the FFW concepts currently in-progress in ongoing soldier modernization programs, see [9].

4.3 Crises Management and Social Networking

As described in [125], an Internet collaboration tool, a structured wiki application, (TWI-KI), has been created to support intra- and inter-organizational collaboration, to survey collaboration methods including internet relay chat and other collaboration tools categorized as synchronous meetings. Inevitably, as network-based communication has increased and multidimensionally developed, group-oriented communication tools have been extensively studied both as a concept and framework. Group-oriented communication tools differ from conventional unicast-based communication tools and are based on group-based communication tools, as discussed in [141]. Communication systems can draw on various concepts and network architectures, as explicitly elaborated in [141]. Presently available collaboration tools can be synchronous or asynchronous collaboration services, such as tools for conferencing, data and application sharing, and tools for workflow management, as described in [107], including videos and frames from a battlespace. One of the collaboration services options offered is the collaboration-capability maturity model, as introduced in [107]. Especially peer-to-peer networks are versatile in allowing each member in a Peer to Peer (P2P) network to act as a client or server as described in [83]. Peer-to-peer networks have been combat-tested with an embedded protocol, which effectively repairs the network with the remaining nodes available, as discussed in [83]. Present collaboration tools enable video streaming in a mobile network, as discussed in [130]. This function can be exploited in social networks in civilian contexts provided with adequate communication capabilities, including bandwidth and Quality of Service (QoS), see [130].

The concept of Integrated Platform for Autonomic Computing (IPAC) described in [84] aims at delivering a middleware and service creation environment for developing embedded, intelligent, collaborative, and context aware services in mobile nodes. This technology is suitable for non-governmental organizations in crises management areas. The concept is planned for multilateral operations where human-relief operations are executed by relying on different Graphical User Interfaces (GUIs) and transmission protocols, see [84]. The requirement for reliable communication links between the military and first responders is recognized. The proposed solution is based on the multiple user objective system. This system represents a type of communications network being built for the US Department of Defence and is defined and provided by strategic command, as discussed in [132]. The goal is to streamline and empower the existing communication processes for improved and faster execution of operations.

In emergency mitigation and response settings, Shared Situational Awareness becomes indispensable, as argued in [65]. To be able to transfer military C^2-concepts and protocols to heterogeneous organizations requires an understanding of the prevalent processes, resources and cultures. As indicated in [65], emergency managers need an information and communication structure that supports creative and adaptive behaviour throughout a distributed decision-making network. Distributed collaboration asks for support for informal communication, opportunistic interactions and reliable and frequent shifts between asynchronous and synchronous modes, see [33]. To meet these needs, [33] describes a study in which open communication server was applied with encouraging results.

Experiences where a tactical collaboration tool has been useful are discussed in [68]. A tactical collaboration tool represents a tool within the defence collaboration tool suite, see [68], in asynchronous and synchronous modes. The starting point of [21] is that the amount of data available for a mobile user in daily life has increased due to the increase of smart telephones and Personal Digital Assistants (PDAs). Moreover, [21] argues that both community-context and spatio-temporal-context information must be taken into consideration in collaboration processes, and, for example, a tool named the context-aware adaptation service, which uses Web Service (WS) technologies, has been created, see [21].

4.4 Network Centric Warfare (NCW)

The term Network Centric Warfare (NCW) can be defined as follows: NCW is a means of organizing a force by utilizing modern information technology to link sensors, decision makers, shooters and weapon systems to help warriors work more effectively together in order to execute the commander's intent and successfully carry out the mission [4]. The concept of

NCW operations permeates every aspect of present military operations, and network centric operations' industry consortium provides guidance for network centric operations, see [136], for example, Ball's Aerospace's collaborative technologies and solutions group suitable for NCW, see [66]. Tactical operations depend on a reliable capability to communicate and a mobile backbone enabling NCW, as indicated in [133]. Moreover, recent innovations in nanotechnology are seen to foster the capability to communicate at the level of a single warfighter, as argued in [137]. Obviously, for practical purposes, the innovations in wireless technology are well received. The utilization of innovations is evident in the field of nanotechnology, especially among Nanoelectromechanical Systems (NEMS), and offers new solutions with antennas, see [137]. However, the most critical limiting factor in an NCW environment equals the limitations of human proficiency, the rate of forgetting, as pointed out in [81].

NCW is based on human and organizational behaviour, and represents a way of performing tasks, a type of mental mode, as discussed in [119]. NCW has been formulated to foster dynamic operations in a battlespace, as described in [119]. To evaluate the performance of NCW-systems, a net-centric evaluation framework is proposed in [71]. To empower the overall communication effectiveness of an NCW environment, a tool named the multi-interface communications software utilized in messaging and tracking softwares is introduced in [80]. It is a robust messaging platform for heterogeneous communications equipment, which provides uniform communications leveraging in all the available transmission modes.

The NCW elements interacting inside a communication system can be viewed as nodes in the network, as described in [35]. The taxonomy of the nodes can be based on describing the nature of the nodes categorized by using two concepts: value symmetry (whether the nodes differ significantly in their importance) and homogeneity/heterogeneity (whether the nodes are similar or dissimilar), see [35]. As indicated in [105], in military operations qualitative information supports quantitative data, providing experts' views and reference knowledge and perspective. When this expertise is combined with decision making processes, the cumulative nature of the process can support the tracking of the steps in decision making – from events to data, to sources, to decisions, and back again, see [105].

As described in [4] and [131], an NCW enterprise focuses on the power that can be generated from the effective linking or networking of a collective enterprise. The type of enterprise can be seen as a distributed sensor network described in [131]. Similarly, interoperability in NCW can be exploited in the collaboration of several governmental organizations, collecting real-time SA and intelligence information, see [15]. This utilization is important in the mobile systems providing critical data [154]. Yet, at the level of a warfighter, the remaining challenge continues to be how to seamlessly interface loads of disparate stand-alone SA and close air support systems into an NCW infrastructure, as discussed in [43]. One solution can be the variable message format -based data links, see [43].

4.5 Networks

As discussed in [20], the scalability of network architecture is essential for providing connectivity and QoS in future combat systems in heterogeneous network environments and communication robustness in a Mobile Ad Hoc Network (MANET). Functional mobile military networks are vital for executing the tasks given in NCW and in network enabled operations, as described in [85]. The objective of both is to reduce the required time to engage and execute the operations, in other words, to shorten the time required for the observe-orient-decide-act loop, discussed in [85]. To effectively execute NCW, the present significant challenges in tactical networking environments have to be solved. The wireless and ad hoc nature of these networks means unreliability in connectivity, limitations in bandwidth and variable latency. Furthermore, to realize speech recognition for C^2 purposes, a modified neural fuzzy network is proposed in [89]. Besides this, soldiers on the move require robust communications that are functional both beyond line-of-sight and in line-of-sight, as discussed in [5]. Presently available communication solutions are based on combat net radios, dominated by the enhanced position location reporting system and the single channel ground and airborne radio system, see [5]. As last mile solutions, WiMAX technology can be utilized in providing converged video, voice and data services to mobile users, as described in [14]. COTS products are deployed to boost the performance of the forward-deployed warfighters. However, these COTS-products face several implementation challenges, as indicated in [40]. Wireless Sensor Networks are viewed as an interface between the physical environment and the networked world, as discussed in [3].

Military network environments comprise varying types of networks. The most typical networks include: Wireless Networks (WN) with integrated services [34], sensor networks [41], wireless sensor networks [3], WSNs applicable in event detecting [10], Wide Area Networks (WAN) [57] and Ad Hoc Networks [129] with modifications, such as vehicular ad hoc network and MANET [95]. Tactical mobile mesh systems belong to this group. These network types are supported by Wireless Fidelity, IEEE 802.11 Wireless Local Area Networks, satellite communications, and microwave communications.

The broadcast characteristics of WNs provide an opportunity to deal with unreliability, and WNs exhibit significant data redundancy in that there is a substantial overlap in the information transmission to the nodes, as discussed in [54]. The challenge in Packet Radio networks is the interference (thermal noise) generated by the network itself. In [16] it is proposed to use wireless network control systems to facilitate optimal combination of protocol parameters which can support robust real-time wireless communications. In order to create an adaptive QoS to mobile hosts, architecture and adequate bandwidth levels along with reliable services are necessary, and, to fulfil this task, the Integrated Service (IS) networks with mobile hosts, while the mobile reservation protocol is implemented in [34] to exchange state information in the wireless environment. The primary common feature of WNs is the scarcity of spectrum, and the secondary one is the problem of integrated scheduling power control discussed in [12]. When an airborne element is added, such as a UAV, the use of WNs becomes challenging because of the characteristics of unstable environments, see [129].

Important for military applications, sensor networks are particularly crucial in a battlespace, for their capability to collect data about enemy actions, as described in [42]. Sensor networks can be beneficial in various surveillance applications, in tracking targets and detecting events. Since sensors accrue vast amounts of unsorted data, [37] proposes a general resource manager as a consolidated approach that takes into account knowledge from all the sensors prior to executing a given decision making process.

WSNs have been widely used for agricultural and environmental monitoring [3] and in industrial applications [120]. WSNs can be utilized to improve localization accuracy; they typically consist of a high number of small, low-cost sensor nodes distributed over a large area, as described in [10]. Each node is usually equipped with multi-type sensors, a wireless radio transceiver, a small microcontroller and a power source, and, once sensor nodes collaborate among themselves, they establish a WSN, as described in [24]. A WSN is composed of a sink node (base station) and a vast number of sensing devices, see [91]. Currently, wireless sensors and mobile phone users can perform sensing collaboratively and complement each other by replacing WSNs [127] and thus support the tools of social media. The Security Adaptive Self-Organization for Wireless Sensor Networks algorithm was created in [7] to establish secure group communications, and to reduce the challenges of link-layer communications and the energy consumption of the WSN and their nodes.

As discussed in [113], ad hoc networking technologies are able to fulfil the needs and requirements set for tactical networks in the digitized battlespace. Ad hoc Wireless Networks consist of a collection of wireless nodes, all of which may be mobile or static, and dynamically create a wireless network among them without relying on any infrastructure or administrative support, as discussed in [23]. To improve the throughput by using low cost COTS-products, a multi-channel multi-radio solution was viewed in [146] to be a promising solution. In a battlespace the concept of wireless mesh network can be utilized, see [146]. An extension of wireless networking is the intelligent transport system, and a module created for this purpose is called the vehicular ad hoc network [95]. Mobile features of transmitting multimedia services over a wireless medium features problems with channel capacity and channel statistics, as indicated in [1]. The increased demand of these services is noticeable in tactical applications which must insure high Quality of Service. In other words, high mobility combined with frequent changes in topology variations makes spectrum management challenging in a battlespace, as pointed out in [153]. As discussed in [157], high mobility results in fast and frequent changes in interference conditions. Tactical networks are typically hierarchical and involve heterogeneous types of radio communications, see [153]. On the other hand, the velocity of a dismounted soldier stays at or below pedestrian speed of two meters per second and a squad typically executes operations around the area of 40 meters in radius, thereby improving the capabilities to communicate. The adoption of an Unmanned Vehicle (UV) offers aid for wireless ad hoc networks in the role of a communication node, as described in [129]. Ad hoc networks can create a UAV access net ensuring communication among mobile or stationary users, see [25]. These ad hoc networks support Blue Force Tracking, as described in [96].

In mobile settings (MANET) security issues remain crucial, as discussed in [118]. Certificate revocation methods used in the certification system for MANETs are discussed in [118]. Security issues surfaced also in the case of [147] in which a private key generator was created to increase the level of security among mobile users. To improve the performance of MANET, an automated design manager was introduced in [154], and a tool for network utility maximization was created in [18]. To boost the performance of MANET, COTS-technologies can be beneficial, as indicated in [29].

Expectations of developing new technologies increase in the field of improving the capability of WANs with virtual machines, see [57]. Similarly, expectations increase towards knowledge networks, which promise to become a useful tool in [18], along with cognitive tactical networks sporting cognitive network design tools of Combat Net Radio, as discussed in [153].

4.6 Free Space Optics (FSO)

The term Free Space Optics refers to a line-of-sight technology that exploits beams of light to provide optical bandwidth connections for communication purposes to transmit voice, video and data at bandwidths of 1,25 Gbps, see [93]. As indicated in [123], hybrid Free Space Optical/Radio Frequency (RF) networks are beneficial for NCW by offering an increase in bandwidth and the capability to transmit high resolution images acquired by tactical sensors. FSO offers a cost-effective wireless broadband backbone that can meet the requirements of the coming city-wide wireless networks, as described in [101], in good weather conditions. FSO can be inexpensively used in range and orientation localization schemes, see [2]. When UAVs are equipped with FSO communication links, operations can be executed without the possibility to become sensed by means of electrical reconnaissance detection, as concluded in [30].

Since FSO serves as a tool for NCW, autonomous reconfiguration of FSO networks is required to receive improved performance, as described in [36], and it is feasible to reconfigure network topologies through a dynamic and intelligent rearrangement of fixed and mobile backbone nodes with high data rates. As discovered in [82], the design concept of a proposed broadband wireless access system based on advanced dense wavelength division multiplexing radio-on-FSO is capable of transmitting multiple Radio Frequency (RF) signals in good weather conditions. The transmission of RF signals utilizing FSO links (radio-on-FSO) combines the advantages of high transmission capacity enabled by optical device technologies and the ease of deployment of wireless links. For example, a distance of 1,5 km can be covered when using a 256-element imaging receiver for FSO communications, with the optical density of -47db and a 30,4 db dynamic range at 500 kb/s with Manchester data coding, with the transmission power of 3 mW, as demonstrated in [88].

As for surveillance, target tracking and acquisition issues related to FSO networks, FSO technology can be combined with optical tags for identification and interrogation purposes, as indicated in [59]. Furthermore, a dynamic hybrid system sharing a common aperture is an interesting solution of FSO in Pointing, Acquisition and Tracking (PAT) applications, as described in [78]. Systems can benefit from utilizing the same components for tracking, acquisition, control signalling, neighbour discovery, and providing a backup communication channel.

Since FSO can provide a secure means for high-speed broadband connectivity, it represents a profitable means to transmit data from various sensors to the data analyzing system. In target recognition, Light Detection and Ranging (LIDAR) sensors together with Support Vector Machine (SVM) and neural network algorithm have turned out to be useful, as explained in [87]. There is an increase in target recognition based on seismic sensors and neural networks in sorting wheeled and tracked vehicles, as indicated in [92]. Laser doppler vibrometer combined with a pan-tilt-zoom camera can be used in remote audio/video acquisition systems for human signature detection [121] and in distances less than 200 meters.

4.7 Unmanned Aerial Vehicles (UAVs)

Unmanned Aerial Vehicles can be understood both as platforms for low-power, low-cost and widely distributed network nodes and as platforms for surveillance and localization sensors used in target tracking, see [39]. Unattended Ground Sensors (UGS) and Robotic Ground Vehicles (RGV) can be used to expand or fill in coverage areas and reduce energy costs in surveillance applications.

When lacking wired infrastructure, unmanned systems have to be powered with a combination of different power sources (battery, solar power). In vision-based tracking pan-tilt gimballed cameras using COTS components can be used as well as calculation algorithms and advanced controlling systems for integrated control of a UAV and an onboard gimballed camera, see [39].

Along with the availability of both low-cost and highly capable COTS-based UAVs 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 [62].

Tracking involves the observing of persons or objects on the move and supplying a timely ordered sequence of respective location data to a model which is, for instance, able to serve in depicting the motion on a display.

UAVs of varying types and sizes can be used in aerial surveillance and ground target tracking, see [128]. To boost the performance of a single UAV, swarms of small UAVs can rely on airborne MANETs as indicated in [25]. Transmit antennas are significant in the process of operating UVs as indicated in [26]. When swarms of UAVs are used for navigation, localization and target tracking, information synchronization plays an important role, see [122]. In co-operative target tracking based on a team of autonomous UAVs, specific flock guidance algorithms have been developed. In present battlespaces, miniature Unmanned Aerial Vehicles seem to become increasingly significant among surveillance applications, as shown in [116].

4.8 Robots

Since human beings interact with robots, a common language for controlling robots and other agents is required. For this purpose [6] introduces an architecture of Everything is Alive Agent System. It is modular and scalable and an end-to-end-platform is used. The EiA agent system aims at a near-future world, where computing is pervasive and where people, vehicles, equipment and data sources and applications are able to communicate with each other. Once communication and control systems are reliable, a robot can be utilized for various purposes with applications suitable for both military environments (ME) and crises management environments (CME).

The term military environment (ME) comprises all the thinkable environments, in which military operations are to be executed on land, in the air, at sea, and in the electromagnetic spectrum. Examples of operations cover defensive operations, attack missions, operations in urban terrain and coastal operations. Less typical operations include rescue operations and search and destroy operations.

A crises management environment (CME) is an environment encountered in peace supporting operations and peace enforcing operations including society rebuilding efforts and other types of activities that are part of Military Operations Other Than War (MOOTHW). These operations typically include friendly forces, neutral forces and an adversary (red force). The entities involved can execute operations parallel to military operations.

Service robots can be equipped with sensors capable of sensing vision, motion, heat and detecting intruders by means of face-recognition and navigation systems, as introduced in [99]. The same technology can be used in the environment of service robots when the robot has to recognise a given person to be served or helped, see [13]. For surveillance purposes, autonomous underwater vehicles can be utilized, as indicated in [61]. When the level of automation increases in mission planning processes and when the role of a human being mainly involves defining and supervising an operation, particular types of errors will cease from occurring. In crises relief operations, automated platforms can be beneficial, especially if the C^2-systems support this capability.

The significance of developing cooperative autonomous robots has increased with the growing number and versatility of complex tasks too complicated to be executed by using a single robot. Jacoby [72] argues that Cooperative Autonomous Robotics for Military Application (CARMA) provide a solution and offer a network beneficial for this type of work. CARMA is used for determining how to create an efficient and robust model for distributed cooperative robots to enhance the capability of the overall C^2-process of controlling robots.

The capability of tracking and identifying of people is crucial in operations. In [13] a service robot using an improved histogram-based detection and multi-sensor data fusion was utilized in various operations with improved capability, and attached Radio Frequency Identification

(RFID) tags were relied on for the recognition, identification, location and tracking purposes of people, objects and materiel.

Data fusion is used to analyze the data gathered from the battlespace. These data can be gathered by means of various types of sensors, data-bases and different actuators. Data fusion can be utilized in improving the performance and accuracy of various types of detection, tracking and surveillance systems as described in [13].

The performance of neural controllers with algorithmic vision-based methods can be beneficial in navigation processes, as introduced in [22]. These described technologies can be applied in developing the robot soldier. The QinetiQ North America Company has launched a project named Special Weapons Observation Reconnaissance Detection Systems aiming at arming a Robot Soldier with a lightweight weapon system, as discussed in [152]. The key in this work is to succeed in defining and constructing reliable human robot interaction for the used systems and applications, as described in [11]. In ubiquitous computing environments both graphical user interfaces, see [67], and human robot interactions are essential, see [100].

4.9 Service Oriented Architecture (SOA)

Service Oriented Architecture promises to enable utilizing and operating complicated systems. SOA enables organizations and entities to enhance interoperability and collaboration, see [144], and foster the reusing of components and interfaces. SOA can be used in service collaboration. With the correct framework SOA allows publishing services, in particular, in a service registry and exchanging data through the Simple Object Access Protocol (SOAP), see [144]. SOA offers a flexible solution for systems integration, applications, protocols, data sources and processes to form a cohesive system that supports the execution of critical BPs, see [117]. SOA can be used as a collaboration tool in crises management and industrial environments if the challenges of real-time SOA [117] are solved. In order to successfully execute BPs, Business Process Execution Language (BPEL) is required, as argued in [60]. In military systems the adoption of SOA principles can beneficially result in the overall improvement of system flexibility and maintenance. SOA provides the user with richer information sets via the ability of Web Services to reach out through the networks, see [74]. In the process of achieving greater interoperability, SOA can be used by utilizing service oriented migration and reuse technique, described in [90].

In NCW contexts SOA has been recognized to act as an enabler of services. SOA is an architecture style that encourages loose coupling between services to facilitate interoperability and the reuse of existing resources as described in [108]. SOA is seen as a tool in enhances agility to handle the changing dynamic evolution needed in network enabled capability, see [94].

Network Enbled Capabilities comprise all the thinkable capabilities networks can offer. This means that decision entities and command and control elements as knowledgeable as possibe. Actors and decision making entities are thus optimally connected. Sensors and shooters are tightly connected with decision makers.

The concept of Network Enabled Capabilities can be viewed as an integration of assets to fulfil a mission objective in military settings, as discussed in [130]. Network Enabled Capabilities fosters SOA to create flexible forces, which are constantly ready and deployable, capable of dynamic changes and evolution to achieve realizable effects. To benefit from SOA in an optimal way, organizations require a comprehensive and applicable SOA governance framework to implement the management and control mechanisms in the system, as argued in [70].

Lund et al. [97] argues that Shared SA is in a central role for network-enabled capabilities, as described in [97]. In NEC, SOA is most commonly realized through Web Services GUIs, as discussed in [67], using Extensible Markup Language (XML) formatted documents, see [97]. As evident, XML WS have been recently used to implement SOA enabling the building of BPs by dynamically calling services from the World Wide Web.

SOA is an open concept and supports plug-and-play capabilities of heterogeneous software and hardware components, with the implementation of Web Services, which is probably the most popular implementation of SOA, as discussed in [156]. For this reason, SOA has been selected as the architectural solution for the C^4I^2SR systems for the Finnish Defence Forces [76]. SOA is seen as an enabler in crises management organizations for delivering data and services across political, organizational and cultural boundaries as well as addressing the issues of information sharing regardless of where required data is stored, as concluded in [49]. The global information grid is an essential vehicle in the execution of SOA and for the transformation of data.

4.10 Training

As for training and simulations, warfighters obviously develop their skills by training in versatile environments. As indicated in [106], in military experimentation, qualitative information supports quantitative data, providing perspective, expert opinion, and reference knowledge. Increasingly, the training of military operations in urban terrain has become significant. In the process of developing a soldier system for the FFW, simulations can be utilized. As an example, a method to generate a dynamic virtual prototype has been created in [50] and an analysis was carried out to determine the effectiveness of FFW equipment and ensure the equipped FFW performance in a small combat unit. Furthermore, the overall performance in an environment other than MOUT was also studied, see [50]. Earlier studies explore soldier tactical mission system alternatives in combat, see [58]. Furthermore, the U.S. Army is currently in the process of determining the roles of a 2010-era FFW, as described in [150].

To ensure the adoption of a lightweight high-bandwidth conformal antenna system for ballistic helmets, extensive studies were carried out with the assistance of an advanced technology demonstration, see [69]. To encompass the overall performance of an FFW in MOUT, an evaluation tool, systems decision process, was used to improve soldier lethality, survivability and combat effectiveness in close range.

4.11 SUMMARY

A dismounted FFW has to execute a set of versatile taks in the battlespace. An FFW must be more than just a harness for energy-consuming electronic devices. The constant energy flow required remains a challenge. It is essential to optimize the gear of a dismounted FFW whose most important capability is related to optimized Situational Awareness increased by means of Command and Control and Battle Management Systems. Enhancing the performance of a dismounted FFW presupposes improving the level of situational awareness in order to support survivability and the capability to perform. A possible means to facilitate the performance of a dismounted FFW is offered by COTS -products. Although COTS -products can be seen as possible solutions, they often lack the features related to ruggedisation, variance in electronic spectrum, feature problems related to constant and stable power flow, demonstrate fault tolerance in a battlespace, and cannot instantly be repaired in a battlespace. A COTS-based product for a dismounted FFW's purposes must be replaceable to foster warrior capability and the execution speed of operations in harsh environments. In short, COTS -products must be simple to use and ruggedized.

The goal of this literature survey of existing FFW solutions was to identify missing subsystems. Consequently, there does not seem to exist research work focusing on the problems and proposed solutions outlined in Table 1. At least such studies were not found in the extensive literature review drawing on open sources, but similar solutions may exist in restricted collections of classified material, which remain unavailable.

5. TOWARDS THE FUTURE FORCE WARRIOR CONCEPT

The papers P1–P7 produced for this present study focus on COTS-based ideas on how to possibly improve the presently available FFW systems. This is done by introducing plausible ideas to improve SA and COP of a dismounted FFW, and reduce collateral damage and minimize instances of fratricide. The key capability of a dismounted FFW is linked to the ability to utilize the existing gear and resources. Mission planning and execution of military operations as processess can be seen as force multipliers in a military environment.

Maximizing FFW systems' performance requires accounting for the following six points.

First, the improved performance capabilities in mission execution of a dismounted FFW can be identified as the main objective. Technological ideas on how to benefit from WPSN, SOA and COTS -based products are discussed in papers P1–P7. The importance of the military Resource Manager (RM) and Scheduler is pointed out. Military operations can be boosted by executing them as usual Business Processes.

Business Process is a chain of events in which each former process marks a starting point to the next process and this cycle evolves and moves on. Business Process represents a usual civilian process on how businesses are carried out. BP is modeled as a selection of services provided by Service Oriented Architecture. BPs are operated by an inbuilt process engine.

Adopting the BP approach in military settings can result in improved performance capability in allowing for the allocating available resources and capabilities to fully exploit the resources available. The optimal use of existing resources can be facilitated with the assistance of SOA, applying the BP approach, Scheduler, and COTS -based solutions to enhance the performance of a dismounted FFW system. Graphical user interfaces can be seen to be in a central role in developing dismounted FFW gear.

Second, interoperability requirements set for FFW systems can be fulfilled by using tested COTS-based devices, which are carefully embedded into warrior gear. Technical solutions utilizing the performance offered by well-orchestrated SOA and the adoption of the military Resource Manager and Scheduler can improve overall SA and COP of an FFW. In addition, the effects of fratricide and collateral damage can be reduced by improved level of SA and by means of improved capability to perform operations in a versatile battlespace.

Third, the asymmetric and hybrid characteristics of future wars will dominate the future battlespace. The key in increasing troops' performance is to minimize the time in observe-orient-decide-act -loop and the performance in mission planning and execution systems of an operation. A dismounted FFW can be introduced in an NCW environment as a force multiplier. Since every warrior can be seen as a mobile node in NCW, it is essential to maxize the capability of an FFW to collect and forward data. In this manner the command posts can receive data collected from the bottom level, analyze these and merge by means of sensor fusion. This leads us to minimized transmission times from the sensor to the shooter.

Fourth, FFWs' versatile communication systems must be able to communicate with a variety of communication systems embedded into the implemented battle management systems. The communication systems have to be able to communicate with different types of battle management systems to maximize the performance of the FFW system. In addition, an FFW must be able to cooperate with unmanned aerial and ground vehicles and benefit from the data collected by these systems. The real-time data accrued can be instantly utilized in mission planning and execution.

Fifth, FFWs' functionality aims at improved overall performance and situational awareness. To minimize incidents of fratricide and collateral damage, it is essential to benefit from the data produced by utilizing the systems of white force tracking and Combat Identification (CID). The end result can be measured with the analyzing process of the combat effectiveness of an FFW system.

Lastly, all these ideas have to be taken into consideration in warrior training, especially when tactics, techniques and procedures of an FFW are being trained. The use of versatile FFW devices has to be taught to a warrior. All the procedures related to mission execution have to be modeled, practised, analyzed and administered to ensure the capability to perform versatile military missions in a battlespace.

5.1 Future Force Warrior as a system platform for subsystems

The requirement for generating ideas for FFW planning is linked to a threat assessment process. The types of threats an FFW can encounter in a battlespace need to be recognized and introduced. Once the threats of an FFW can be identified and classified, FFW systems and subsystems can be planned. In conjunction with this process, the mission analysis of an FFW must be addressed. These two together, the threat assessment identification process and mission analysis, define the type and level of each warrior and its subsystems. By a careful definition process of systems and subsystems and their functions the performance of an FFW can be improved.

First of all, an FFW can be seen as a System of Systems. It is essential to generate ideas and model the functionality of each system and subsystem. Subsystems related to communication, energy, graphical user interfaces, weapon systems have to be planned in detail. Furthermore, systems of command and control benefitting from the input produced by SOA, the military RM, Scheduler and data provided by various sensors, such as WPSN-related ones and warrior-born sensors, need to be considered in detail. The critical mass of a holistic FFW system plays an important role, as do the requirements set for the need of constant energy supplies.

Secondly, FFWs can be seen as platforms of various systems. It is necessary to combine systems in the form of systems and sub-systems. In communication systems, Peripheral Component Interconnect Express (PCIE) is serving as a connector between various data systems. PCIE is a computer bus for attaching hardware devices into a computer. Hardware can be recognized as devices embedded into the FFW systems, such as digital radio, weapon controls and various communication systems. When PCIE is embedded into FFW constallations, it has to be ruggedized, which increases the components' weight to a great extent [47].

Thirdly, FFWs represent a solution of selected systems and subsystems embedded into a warrior's battle dress uniform. The selected gear can be utilized to solve the challenges of a dismounted infantry soldier performing operations in the future battlespace. This task remains a challenge and militaries keep struggling with equipping their warriors with optimal gear. The key characteristics of an FFW are the communication systems and the means to transmit and receive data in a hostile military environment. The electromagnetic spectrum in a battlespace is unstable and latency times as well as signal strengths and the mobility of a transmitter and transreceiver vary depending on the operation. Capability to communicate is the key for sustained performance.

The purpose of generating ideas concerning FFWs is to ease warfighters' tasks and facilitate optimal utilizing of the existing gear available. Both COTS- and Government Off-The-Shelf (GOTS) -products can be exploited, although Military Off-The-Shelf (MOTS) -products represent the most tailored solutions produced to satisfy the needs of a military end-user only.

Planned for commercial and recreational use, COTS -products tend to be light weight and produced of inexpensive materials, which makes them affordable and dispensable. In FFW -programs, the emphasis is on the size, weight, and power of the system. Fielding systems on vehicle platforms ensures saving enough space and energy, because a warrior is not carrying these mounted items. When these items are to be integrated in dismounted warrior platforms with limited space and energy supplies, complaints begin to be filed since implementing heavy equipment on a human body comes at a price

This study views a dismounted FFW as a product-line warrior. The categorizing aligns the warriors' equipment and their capabilities with their duties in a given military organization allowing for cost-effective and optimal utilization of own troops and their respective capabilities. By using COTS -products, a warriors' electronic skeleton can be created and structured as a system platform for subsystems, as outlined in Figure 4.

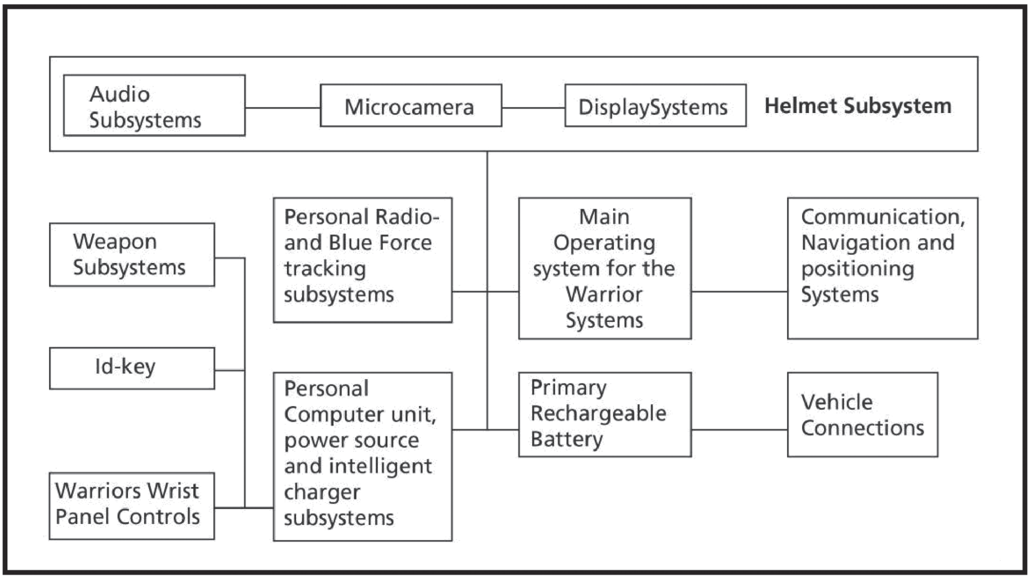

Figure 4. Warriors' electronic skeleton as a system platform for subsystems.

A system platform for subsystems, the FFW -concept is tailored to fulfill the requirements set for a dismounted warrior. Battlespace corresponds to the environment in which military operations are executed. Battlespaces can be located on ground, be airborne, in urban territories, jungles, forests, mountains, at seashore, in deserts, or in the electromagnetic spectrum. A system platform as a warriors' electronic skeleton is planned to meet the set requirements of an FFW.

Militaries continue to face transformations in order to meet the requirements set by the 21st century and beyond. For instance in [19], tools of augmented reality have been used to insert virtual entities into the real world, attempting to create a low cost, repeatable, and effective substitute for fully-manned live training, especially in urban training. A variety of advanced weapon systems and intelligent ammunition have also been developed, as well as drones of various types. To boost the performance in C^4I^2SR, specialized communication devices have been designed. Various types of future combat systems programmes have been ongoing for over a decade, see [20]. The aim of these programmes has been to develop network-centric concepts for a multi-mission combat system capable of rapid and decisive deployments. The objectives of these programs target enhancing SA, survivability, and lethality within a force that is available across the full spectrum of operations.

The objective of these various future combat system programmes is to allow army commanders an exponential increase in combat capabilities to the joint force, as discussed in [150]. The role of the networks is to empower soldiers and leaders with information and decision superiority and improve overall combat performance. The role of enhanced C^4I^2SR is planned to maintain the overall network-centric capability for the operations executed by an FFW.

A practical problem arises with the vast amount of data collected via versatile sensors and tracking systems. Besides, different levels of warriors need different types of data. Although the collected data are vital, warriors' main function remains to fight instead of checking various monitors. Furthermore, there will always be disturbances in the electromagnetic spectrum, and the QoS and transmitting power together with the limited bandwidth set limitations to the ubiquitous communication systems. As Figure 5 indicates, the possibilities of battlespace communication are versatile. Almost all the sensors utilized are linked together to collect data for blue force tracking and combat identification and to improve SA.

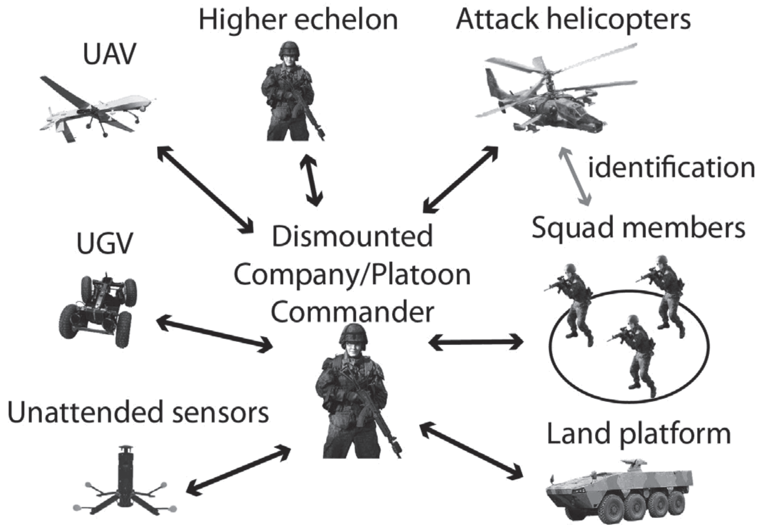

Figure 5. The types of possible communication platforms serving as sensors and network nodes.

The problems related to data distribution are linked to the present existence of various devices and system interfaces. Battle management language serves as a common language enabler between gadgets and interfaces, as is evident in the case of nearly ubiquitous swarms of Unmanned Aerial Vehicles.

Since terrestrial systems alone do not enable the dominance of the full battlespace spectrum, militaries view space as a vertical extension of a battlespace. Capabilities relating to battlespace can be identified as another set of key force multipliers in ensuring success in military operations. An FFW has to be able to be connected to all existing systems in order to use the armament of a higher echelon and maintain constant SA. Moreover, the task of an FFW is to collect new data input for higher echelons to be utilized for a timely and accurate updating of the COP. The communication requirements of an FFW are depicted in Figure 6.

Figure 6. The Future Force Warrior requirements for constant communication.

5.2 Challenges in Military Operations

Defining the constituents of the dismounted Future Force Warrior –concept presupposes identifying the challenges in military operations. This allows for idealizing and planning an FFW system in detail. The result of successful idealizing and planning is a starting point for the creating process towards a functional SoS. In military operations everything is done to minimize casualties and prevent fratricide, as described in [134]. Obeying the Rules of Engagement (ROE) is essential as well. The ability to identify a warrior in the battlespace early enough is also crucial. For successful identification, as outlined in [155], both an interrogation unit and a responder unit are necessary. This requires an optimal distance between the warriors and a functional identification system. In case the identification system does not reply, a human being makes the decision of employing deadly force. This decision is based on the tactics, techniques, procedures, and the visual signature of the uniform, weapon and gear.

An example of a practical challenge in a military environment is that a location device gets stolen or misused by a third party. This is, an insurgent may try to pass as and function as a member of the white force. P1 proposes a solution to this challenge. The tracking devices can be pre-coded and tied in pairs in advance before entering a battlespace to prevent the stealing of the tracking device. If paired devices are torn apart, they become dysfunctional. After the separation process, the devices must be repaired and re-coded by the operator.

When examining the targeting process and the role of ROE, tactics, techniques, procedures, in other words, whether or not to open fire, the Detect, Identify, Decide, Engage, and Assess (DIDEA) –approach becomes relevant. The DIDEA -process provides an iterative, standardized and systematic approach supporting targeting and decision making, being generic enough to be used as a systematic process for C^2-node targeting and decision making. Separate actions in the DIDEA-process are as follows, see [115]:

Detect: The process of acquiring and locating an object in the battlespace by analyzing 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 combat identification tasks are accomplished.

Decide: The decision making process that follows the detection and identification phases. This is the most generic step in the process and the step in which 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 the mission. In case 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?

Engage: The execution of the selected weapons in a selected order starting from the most danger- ous target moving on according to the planned 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. The DIDEA-process in a simplified form is depicted in Figure 7.

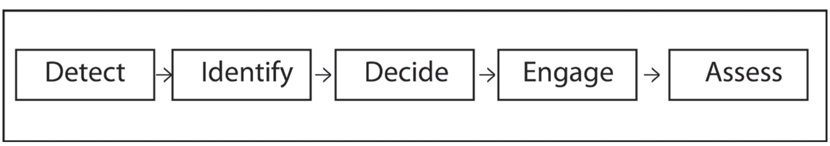

Figure 7. The simplified DIDEA process [115].

The processes related to the collecting of data are vital. Parts of the existing WPSN -systems can be used to collect the required data. When the critical data have been collected, these data have to be transmitted and quickly analyzed to be used for evaluating different courses of action. Mission success depends on accurate mission analysis and a timely evaluation process of the collected data. Improved SA results in optimized time for mission execution and simultaneous minimizing of casualties. This can increase efficiency and lead to minimum recovery times. When combining increased situational awareness with appropriate courses of actions, the overall own troop efficiency can be optimized.

When commanders have access to updated reconnaissance data for mission execution, they are able to analyze different courses of actions. This can be done with the assistance of SOA, the military Resource Manager and Scheduler. Commanders are also able to calculate the pros and cons to evaluate the best possible method to operate in any scenario prevailing. Business Process-like thinking can be used in order to possibly optimize the resources available. Once the miltary decision making process has been completed, the most effective means of execution can be implemented to help maximizing the performance of own troops.

As for shared SA, it is crucial to be able to distribute the collected data rapidly and accurately. This can foster operational success in military operations. This is relevant especially in joint operations, in which the effective distribution of courses of actions and shared SA are crucial.

5.3 Future Force Warrior Product-line Warriors

The performance requirements set for an FFW can be optimized when we deal with FFWs as product-line warriors, since an FFW has to be able to execute versatile types of operations in a battlespace. The types of military missons may vary a lot in variety and tempo. To meet these varying demands set for a dismounted warrior, a selection of warriors capable of executing versatile missions needs to be available. When the tasks of designated levels of warriors and warrior levels can be defined, the optimizing of resources can be easier for commanders in a battlespace.

An FFW can be viewed both as a combination of selected gear and also as a combination of pre-programmed capabilities. These capabilities can be gained by integrating WPSN, SOA, the military Resource Manager and Scheduler in the warrior systems. Each warrior system benefits from the performance requirements being specified according to the warrior level. In addition, graphical user interfaces have to be designed for each warrior level. Comprehending communication systems have to be tailored depending on the performance requirements to produce optimized results related to SA at each individual warrior level and COP at the level of military commanders.

FFWs can be categorized as product-line warriors and this categorizing should be preceded by a threat assessment-process as noted earlier. The nature of each type of threat must be precisely modelled, and after this the evaluated threat scenarios need to be associated with necessary response methods. This fosters producing tailored product-line warriors who can be effective in overcoming and defeating varying types of threats in an ever altering battlespace.

Each produced FFW has to represent a product-line warrior of a designated type. Adopting this approach may be advantageous. So far several militaries have purchased ready-made, tailored sets of systems and embedded them more or less randomly into the warrior gear. This acquisition and procurement method of adding new elements into existing systems does not result in a cost-effective means to upgrade warriors' performance because military gear always features impressive price tags. In contrast, product-line warriors feature inexpensive COTS-based gear and have capabilities which vary depending on the given warrior level's tasks and requirements.

Product-line warriors need to represent responses for typical threats in relation to their assigned levels. All the thinkable operations have to be executable at the given warrior-levels. The product-line warriors have to be able to perform in all typical military operations. In addition, human relief operations, such as peace supporting operations and crises management operations must be executable by FFWs. The nature of tasks varies depending on the environment and missions. In the future, cyber-warriors may become applicable as well, but they remain outside the scope of this study.

The product-line warriors have been defined to feature three warrior-levels with respective threat-assessment- and task-based equipment and capability requirements. The FFW as a systems platform draws on warriors' training levels and thus on their C^4I^2SR-level, as described in [150].

As for the proposed three-level product-line warriors, the Basic Warriors are capable of basic defensive and offensive operations. The Readiness Brigade Warriors are capable of more demanding tasks, such as attack, riot-control, and counter-attacks including maneuvers performed in challenging terrain and against highly mobile and armored adversary troops. These troops comprise the best type of reservists below the age of 30. The Special Warriors are capable of the most demanding tasks, such as attack, reconnaissance, MOUT and different types of assault operations in demanding territory and in an extremely hostile environment.

The troops comprising Special Warriors are capable of all demanding operations performed in all types of operations and in all types of terrain. Special Warriors are specialized in counter-terrorist and counter-insurgency operations as well. These troops consist of professional military personnel since the reservists of conscript-based military forces lack the training to perform in missions of this type.

Figures 8 and 9 illustrate examples of the dismounted FFW-systems from the perspective of selected warrior gear at the Special Warrior level.

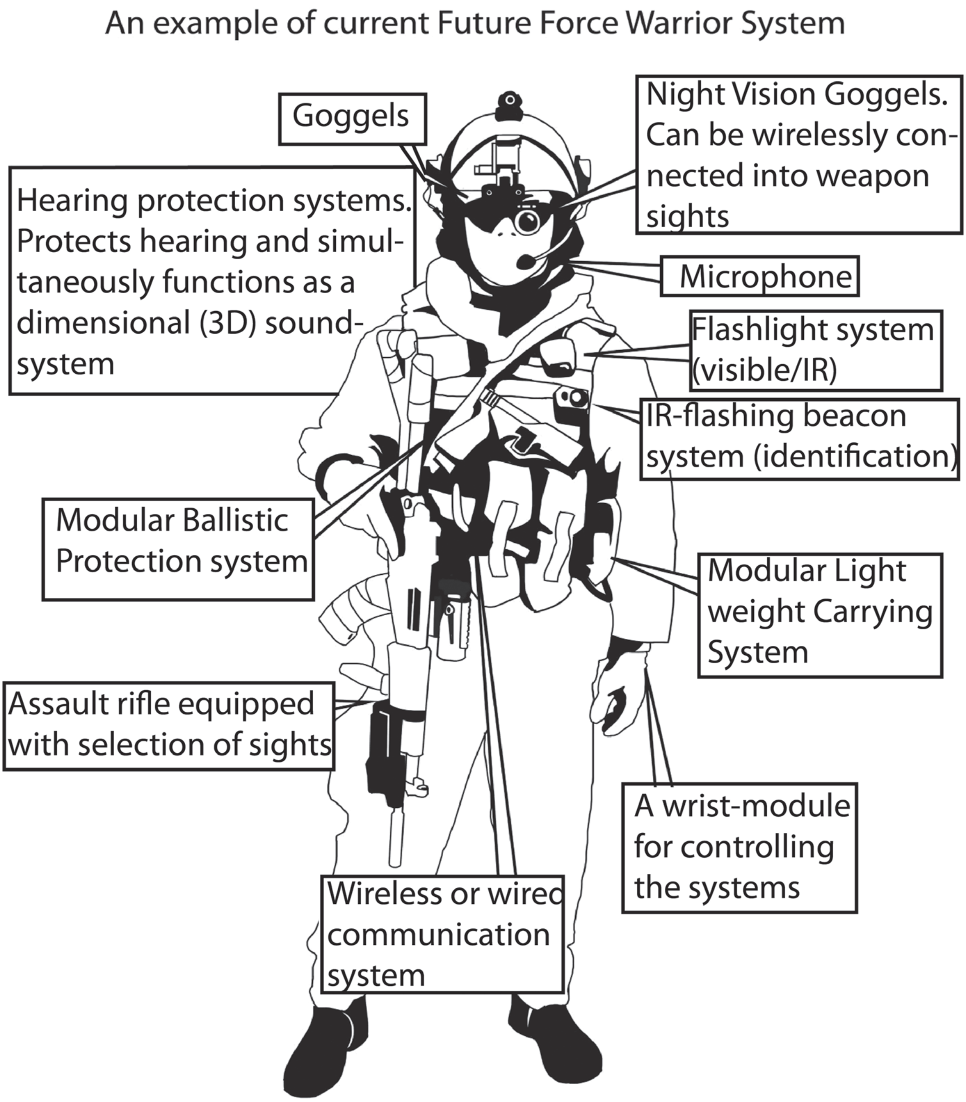

Figure 8. An example of a dismounted FFW with selected gear at the Special Warrior level.

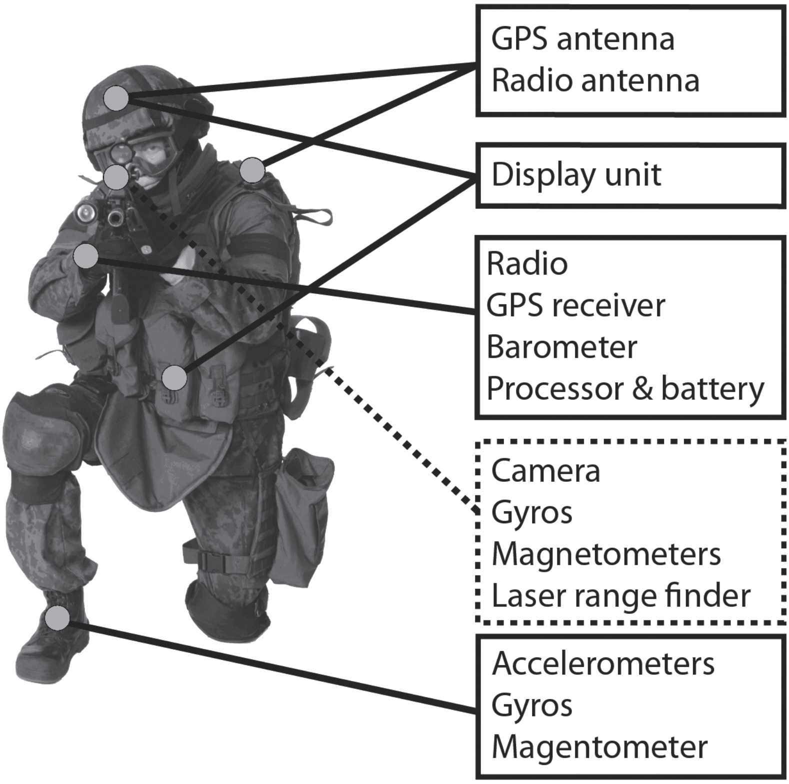

Figure 9. An example of a fully integrated Warrior for location purposes outdoors, indoors and in Military Operations in Urban Terrain for contemporary warfare at the Special Warrior level.

The three-level product-line warriors utilize various means to forward and receive target data by means of palm tops, wrist panels or smart phones, as depicted in Figure 10. At the level of Special Warriors advanced technology can be used to ensure reliable communication means.

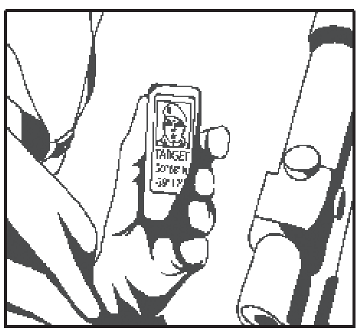

Figure 10. Target data on a screen of a cellular telephone.

At each warrior level it is critical to define the masses of appropriate battle gear selected. As indicated in U.S. Army Field Manual 21-18, the carrying load of an individual soldier should not exceed 48 pounds [52]. When the amount of this mass is exceeded, the performance of a warrior decreases dramatically. The present massess of warrior gear worldwide is from 35 to 36 kilograms.

5.4 Summary

To summarize, the enhancement of FFWs' performance can be viewed to be the most important element in the concept creation process of a dismounted FFW. Technical ideas drawing on WPSN, SOA and military processes as business processes are utilized. COTS-technology can be seen as an alternative platform for military solutions. FFW platforms have to be carefully designed to support the creation process of product-line warriors. Sustained communication capabilities can be seen as a key component in military operations. Communication systems have to be embedded in military systems from the very beginning of a System of Systems creation process. The total mass of warrior systems has to be kept minimal to ensure sustained energy supply until the mission end. Overall situational awareness has to be supported by rules of engagement and DIDEA-process in targeting. Supporting the functional C^2-chain at all warrior levels is vital in the creation process of the dismounted FFW concept. Battle management systems must support situational awareness systems as part of a functional SoS to increase the capability of an FFW in versatile operations executed in an altering battlespace.

An FFW can be seen as SoS. In military environments, it tends to be the norm that some device malfunctions, gets stolen or starts malfunctioning. Systems created for FFWs' have to be modular and easily replaceable to allow replacing the broken item at short time intervals. Sub-systems and devices have to comprise a self-check system which indicates that a particular system is functional. When a system or sub-system is indicated as damaged or dysfunctional, it has to be easily replaced by a new similar device. COTS-products can be seen as an answer to this challenge. If a broken or damaged system is irreplaceable, the system becomes deadweight to a warrior who will discard/reject it automatically.

6. Business Process

Because of the central role of the business process in SOA, the main elements related to business processes (BP) are described in this and the following chapter. In a military environment, an example of utilizing a BP approach embedded to SOA is a military operation consisting of sequenced phases, for instance, an operation labeled as a dismounted company attack, as illustrated in Figure 11.

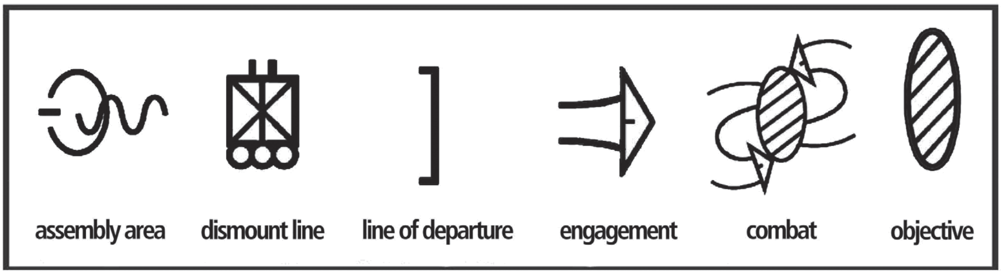

Figure 11. Dismounted company attack as a Business Process.

The variety of services used when viewing a company attack as a BP may include, for instance, reconnaissance, fire support, evacuation, and resupply. These services may be exploited simultaneously by several units or only one unit at a time in a given operational context. This requires efficient orchestration of services to maintain service control. SOA can be seen as an enabler in the process of executing military operations as BPs.

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

The offered services during an advancing dismounted attack are listed in Table 2. Most of these services can be pre-programmed to concern the wanted product-line FFW level. The company commander utilizes various services (fire support orders, location services, medical care, resupply, evacuation, geographical information system -map-service, Blue Force Tracking) while executing the commanded attack from the assembly area to the objective. Table 2 illustrates possible services available for a dismounted company attack.

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

Table 2. List of pre-programmed and additional services in a dismounted company attack.

Fulfilling a requested service requires that the requested service is available and within range. When dealing with Fire Support Orders (FSO), the range limitations of artillery units are critical. As depicted in Table 3, when a howitzer unit executes a commanded task, the requested FSO remains unavailable because the FSO is already reserved and out of range.

<table>
<tr><th>Unit name</th><th>position</th><th>ammunition</th><th>max. range</th><th>reserved</th><th>range</th></tr>
<tr><td>Mortar Company</td><td rowspan="4">GPS-coordinates</td><td rowspan="4">ammunition left</td><td>8,0 km</td><td>0</td><td>OK</td></tr>
<tr><td>Howitzer Unit</td><td>15.0 km</td><td>1</td><td>NO</td></tr>
<tr><td>Artillery Unit 1</td><td>30 km</td><td>0</td><td>NO</td></tr>
<tr><td>Artillery Unit 2</td><td>30 km</td><td>0</td><td>OK</td></tr>
</table>

Table 3. An example of limitations related to the requested service.

6.1 The Business Process and the Resource Manager

The orchestration of BPs in military settings requires a tool, the military Resource Manager. The tool sorts and lines the requested services. Militaries implement the framework of network centric warfare with a continuing need to automate the C^2-tools utilized in military. The tempo of operations must be taken into consideration. The collected data need to be processed, analyzed, verified, transmitted, and finally stored. SOA can be identified as a technology that can satisfy these needs of network centric operations. The starting point in the BP approach to SOA is that the main business operations of the organization are described by SOA BPs. The BPs are chains of logic that request SOA services. In military settings the BPs represent military operations as depicted in Figure 12.

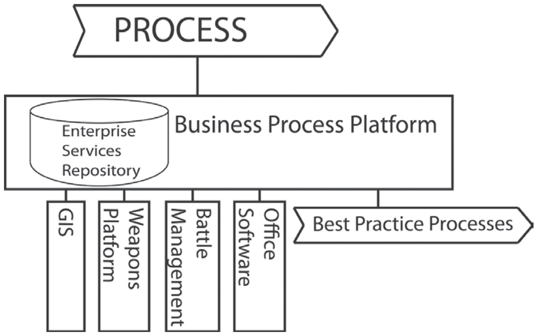

Figure 12. Business Process Platform as a service enabler.

SOA-technology assists performing the processes of military operations. Business processes are executed on a specific business process platform. Services and platforms, such as geographical information-services, weapons platforms, and battle management systems, are linked to the Business Process Platform to produce the best results to the ongoing processes. When an FFW can benefit from the possibilities offered by a successful adoption of BP and SOA, the result may be improved overall performance in military operations.

Figure 13 describes how the Business Process approach can improve the performance of an FFW. Several battlefield sensors gather data from a battlespace. The collected data are then automatically transmitted to be analyzed in a command post. Various battlefield sensors transmit data to the context-aware reasoning layer. In this layer data are converted to context, and inference engine transmits the data to the ubiquitous main layer for analyzing purposes. The data are verified and analyzed and transmitted for execution of the operation.

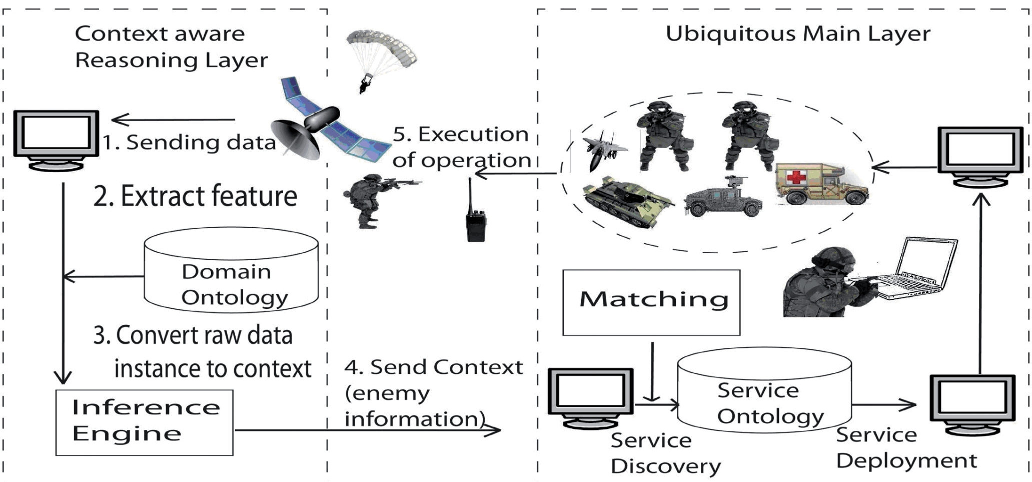

Figure 13. Increased FFW Performance can be gained via successful BP.

Many of the needed services require real-time resources. These services include, for example, collecting SA data and issuing fire support orders. Thus the services and their use must be scheduled and sequenced to sustain the processes. In military SOA architecture, a new element, the military RM, is required to sort out and line up simultaneous requests concerning the requested service. The military RM serves as an element which provides the needed services for User Groups (UGs). Services can be either pre-programmed on demand or be available on demand. The military RM is located at the battalion level. A user sends a request for the demanded service. The UGs are then authenticated, and their privileges are verified, and then the request is transmitted to the military RM. The key functions of the military Resource Manager are: 1) to receive the request of a required service, 2) to organize the line of user groups in the correct order depending on the UGs' privileges and battle-situation, 3) to check whether the service is available and within range, 4) to provide the User Groups with the answer, which is either the requested service or a rejection of the service. Figure 14 illustrates the process.

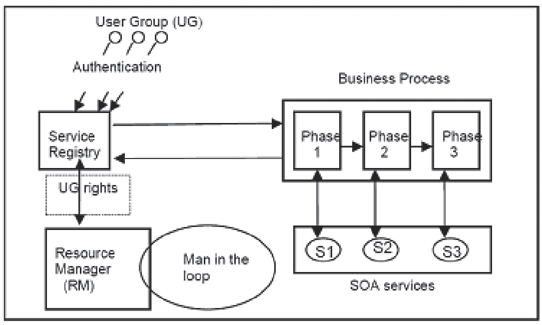

Figure 14. The main idea of the BP approach to SOA.

The military RM functions as a fully automated chain of functions in particular processes. The key function of the person in the loop is to monitor the processes and to interfere in the process flow if an unpredicted anomaly occurs in the process. As the battalion-level military RM is a critical resource, it must be physically protected against enemy actions.

The role of the military RM is central in the allocating of resources in the BP process. The military RM communicates with four intermodules. The military RM graphical user interface provides the core interface between all the presented modules and the Local Area Network (LAN), as shown in Figure 15. The LAN is utilized as a battlefield network or a community network as it can be used on wide area networks. The sharing of networking environment and its resources remains challenging. Similarly, searching for information and asking for resources continue to be challenging when lacking proper search mechanisms. Each module has pre-defined and precise functions. The file and resources sharing module communicates with the military RM GUI in conjunction with the sharing and the download module. The file and resource transfer and download module supports and enables the transfer or download of the searched file or resource from the other node connected to the network. The shared files and resources are listed on the military RM GUI, where the listed and downloaded files can be examined. It is obvious that the same services are requested simultaneously. Therefore, the composition of the military RM needs to be stable and reliable. Figure 15 illustrates the composition and function of the military RM.

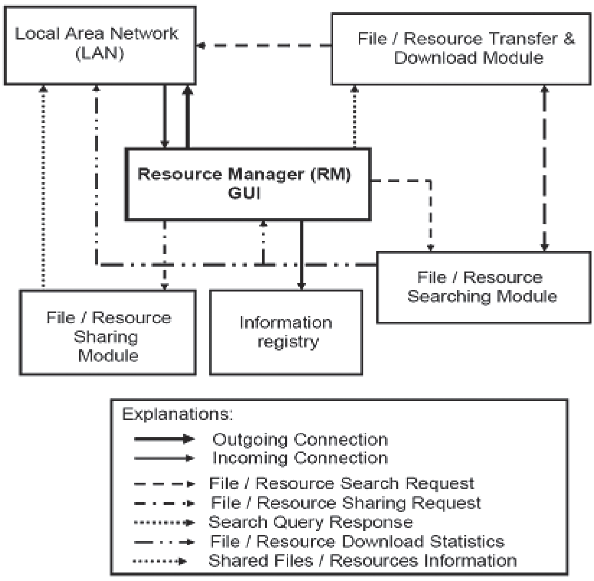

Figure 15. The composition and function of the military RM.

The example below in Figure 16 depicts the processing of Fire Support Order (FSO) requests inside the military RM as an informal Specification and Description Language (SDL) diagram. This action performed by the military RM is essential to proceed in the process of offering requested service/s.

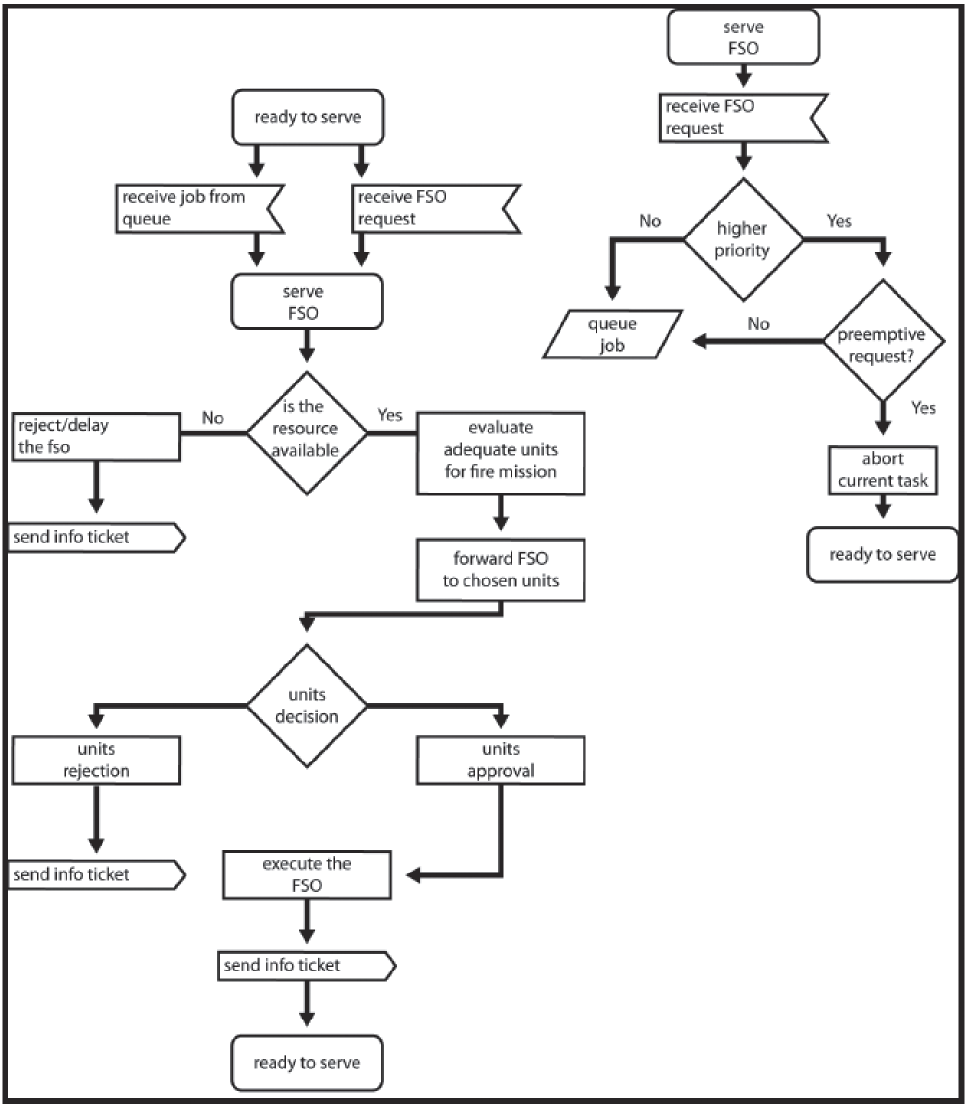

Figure 16. The processing of Fire Support Order requests in the military RM in an informal SDL diagram.

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

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

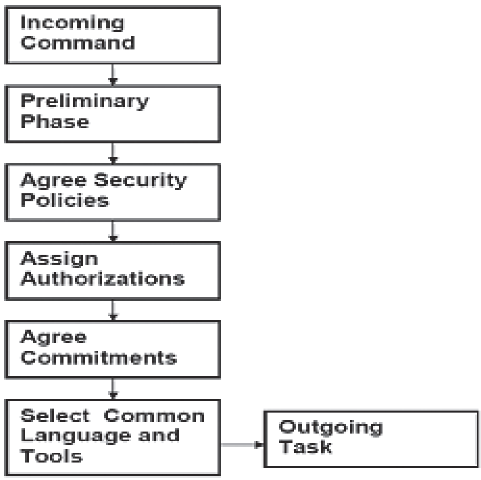

Figure 17. Security, authentication and agreement system.

The described process ends in a phase in which a common language and tools are selected and then it is forwarded inside the military RM. The overall description of the whole concept consists of three major parts and functions: 1) SA comprehending the existing solutions and tools, 2) C^2-tools, and 3) the information repository. These three together enable the C^2 process and saving of log-data for further analyses. These functions presuppose the military RM and Scheduler to share and distribute the tasks and resources. The result of the process is an outgoing task, as described in Figure 17.

To provide for the requested service, the military RM requires one more component. This critical component for the approach of SOA which relies on the utilization of the RM is called the Scheduler, see P6. The role of the Scheduler is to coordinate processes to maximize the performance of resources and to reduce fratricide and collateral damage. The Scheduler enables executing various operations simultaneously but still under strict C^2. The issue of simultaneous operations is solved by the element called the Battlefield Secure Scheduler. This component uses two different methods of sharing calendar, the Pre-Shared Scheduler (PSS) and Dynamic Schedule Update (DSU). The Scheduler functions together with the military RM and utilizes Military Service Oriented Architecture as a process. These elements are featured in Figure 18, which outlines the process of an incoming command/task becoming an outgoing command/task.

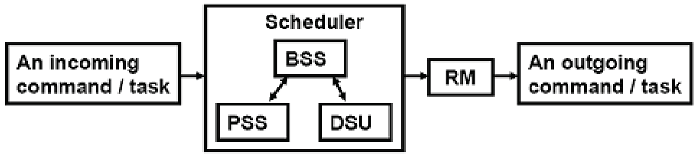

Figure 18. The elements inside the Scheduler and the permeable C²-process.

6.2 Benefits and drawbacks of this solution

The delicate system introduced can malfunction for various reasons. Some of the identified reasons are related to sustaining an adequate level and quality of energy flow to the system. Challenges related to energy sustainability have to be solved to enable the functioning of different processes. The orchestration of the system can also fail because of an intentional enemy action (jamming, a virus, a worm). The system needs to be equipped with an analyzing program, which indicates when the system functions properly. If the system malfunctions and retrieving the capabilities becomes impossible, the system becomes useless for an FFW. This asks for an easily replaceable and fault-tolerant system with inbuilt check-in routines. Othervise, old-fashioned methods in orchestrating services need to be adopted.

By adopting SOA and embedding business processes into the existing C^2-system, the overall performance of military operations can be improved. With the assistance of an earlier missing element, the military RM, limited military resources can be allocated more efficiently to the users requiring for services. When the new invented tool, the Scheduler is implemented together with the military RM into the BPs, the performance of the system can be increased. The allocated resources available can be used optimally. This means shorter execution times, and a higher amount of data for improved decision making.

Offering a service of ubiquitous computing to battlespace commanders increases the possibility of utilizing the available resources. This fosters a rapid decision making process, especially when SOA can be embedded in the decision making systems. As described in [49], SOA must deliver a solution that crosses existing boundaries as well as addresses the issues of information sharing regardless of where that information is stored. A BP-like orchestration of systems and services can improve the overall performance of military operations executed. This can also mean reduction in time required to allocate resources. The improved level of SA may reduce the instances of fratricide and minimize collateral damage.

7. Battle Management System (BMS)

The battle management system is an overall system which interconnects all the warriors in a C^2-environment. In the produced papers (P1 to P7), BMS can be understood as the overall network structure with which each described system is communicating and interfacing. BMS is a system used to combine all the sensors, entities and devices into a higher echelon. BMS enables processes of C^2 to be executed in a battlespace.

BMS provides tactical C^4I^2SR from battle group headquarters down to the level of dismounted warriors. Typically, the system comprises a component-based suite of applications. Figure 19 displays the networks connecting the battle management systems among different users. A BMS consists of different types of sensors, users, interfaces, and connectors.

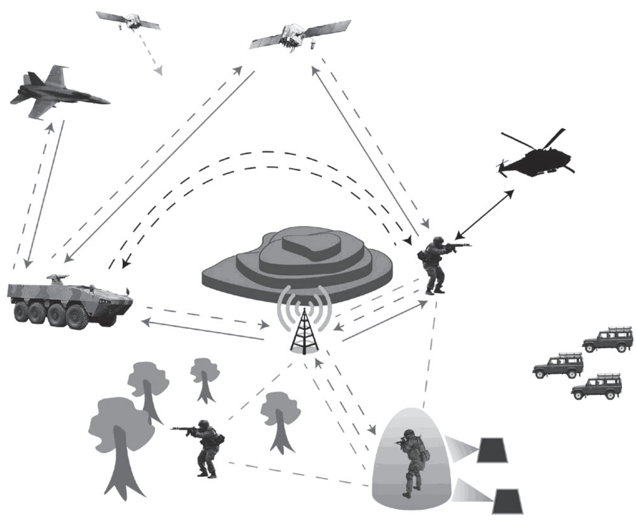

Figure 19. Composition of networks of Battle Management Systems.

A BMS is used in military operations to fulfill a given commander's intent. At the level of an FFW, the individual elements of BMS consist of vehicular mounted and man-portable units, connected to the higher echelons by means of existing Combat Net Radio -systems. The BMS has been embedded in the C^2-systems to provide the overall capability to execute the tasks with maximum efficiency. Figure 20 depicts this system utilized in a battlespace.

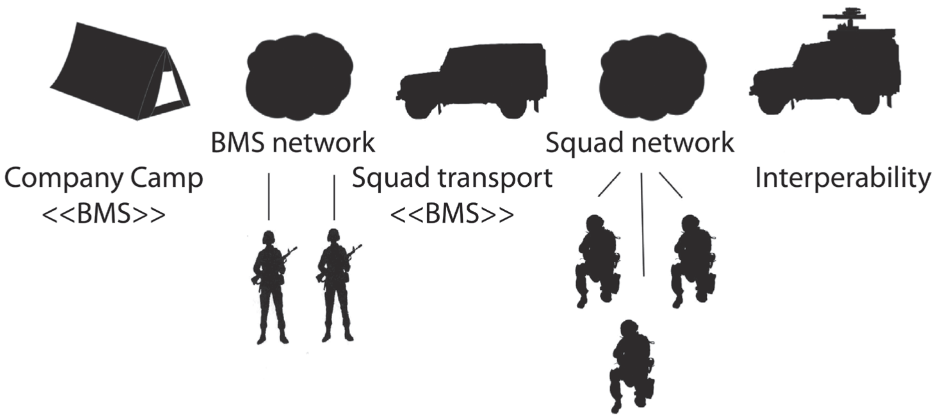

Figure 20. A general overview of Battle Management System Networks.

As for the composition of the BMS and its interfaces, a soldier-level system comprises different devices and subsystems embedded in warrior gear. Warrior gear features a system of its own, in which devices are connected together to enhance each warrior's SA. The soldier-born systems are typically portable and ruggedized.

An FFW's squad is connected to a battle vehicle of a designated type, for example, an armored personnel carrier, a lorry, or a truck. This vehicle functions as a hub and mother-station to the squad. The squad uses the vehicle as a mobile weapon station and communication center and a link or a relay-station. This vehicle transmits the collected data to the headquarters for analyzing purposes. The vehicle forwards the commands to the squad via existing network-systems. Figure 21 indicates different interfaces between individual dismounted warrior systems, mobile battle management systems, and fixed systems of command posts.

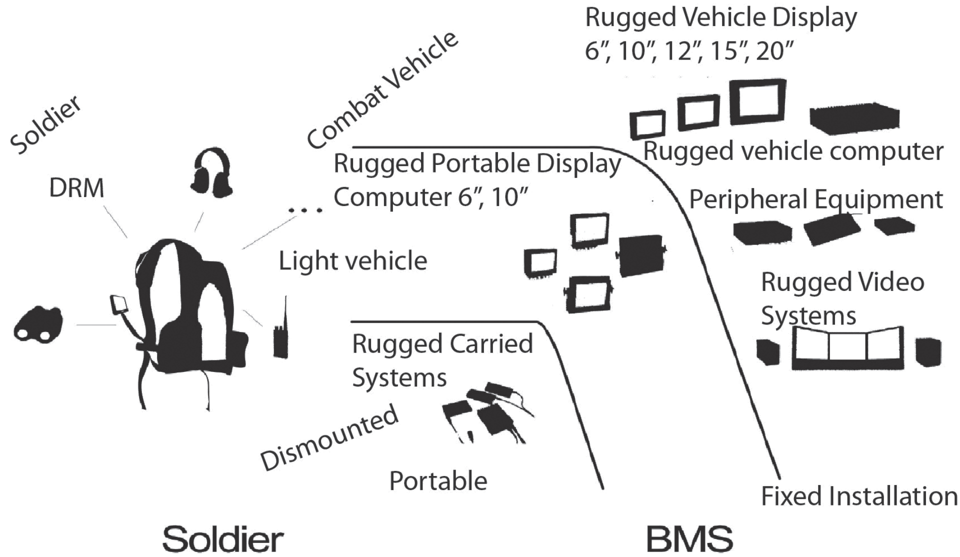

Figure 21. Different interfaces between dismounted soldier-systems, battle management systems, and command posts.

A BMS can be embedded in the gear of an individual soldier, or as part of a C^2-system of a combat vehicle. When embedded in armored fighting vehicles, or infantry combat suits, BMS become the basic level of the tactical C^4I^2SR-network. BMS commonly relies on information collectively gathered by the unit's elements. Specific targets are marked on the BMS displays, providing clear and specific SA to each combat team, allocating tasks and coordinating fire and maneuver over a large area, without the need for visual coordination. In Figure 22 BMS is depicted as a warrior-mounted system.

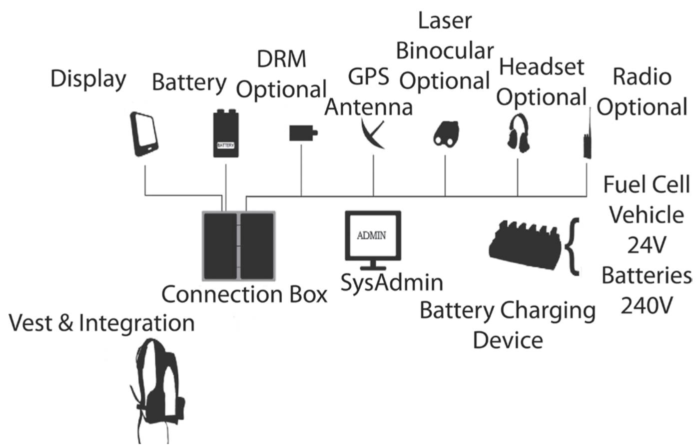

Figure 22. An overall description of a BMS at a dismounted FFW level.

BMS relies on a comprehensive language between the machines and interfaces used, Battlefield Management Language. The objective of BML is to act as an enabler to describe a commander's intent to be understood by both live forces and automated systems for simulated and real world operations see [126]. As described in [126], BML can be used for the interaction between C^2 systems and simulation systems. The resulting language is intended to be applicable in simulation systems and also in operational C^2-systems and robotic systems. Figure 23 indicates the communication systems between soldier systems and smartphones.

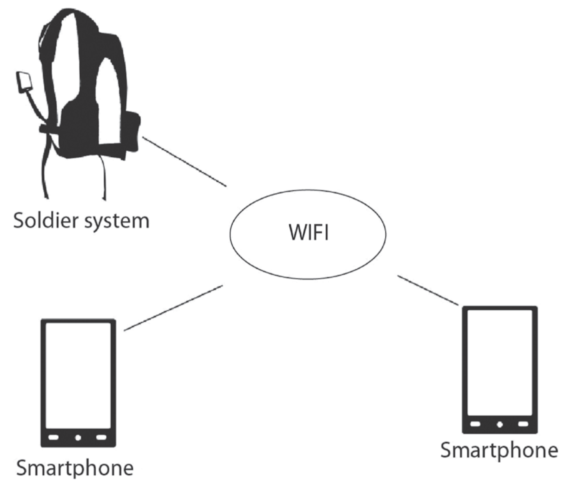

Figure 23. Communication system between smart telephones and soldier systems.

Over a number of years, considerable efforts have been made to develop mechanisms to provide interoperability between C^2-systems and simulations. Initially, these efforts were predominantly driven by the need to reduce the costs associated with inputting data into simulations that supported C^2 training. The development of digitized C^2 systems and the opportunity to utilize modeling and simulation tools for courses of action and mission rehearsal and work on robotic forces have meant that there is an increased demand for interoperability across training systems.

A BMS can contain different types of displays capable of exporting battlefield geometry overlays, digital and scanned maps and route navigation. A BMS may also contain a fire support system including fire support from a single gun up to artillery unit resources, such as an artillery regiment.

A BMS represents an overall system which interconnects all the warriors in a C^2-cycle. Since BMS is connected to various entities, the functioning becomes sensitive to failures and may malfunction. The energy flow has to be constant to enable the functionality of the systems as is the case with the challenges concerning connectivity. If a system malfunctions, old-fashioned manual tools (maps, telephones, radios) and other systems based on voice-commands need to be taken into active use to replace the lost functionality of the described BMS.

When everything functions as planned, a BMS can be viewed as a system used to combine all the sensors, entities and devices into a higher echelon. A BMS enables the processes of C^2 to be executed in a battlespace. BML can be used in the interaction between C^2 systems and in tools for course of action planning and analysis. When BPs are embedded together with the assistance of an appropriate Scheduler, a graphic user interface of an FFW may appear in the form depicted in Figure 24.

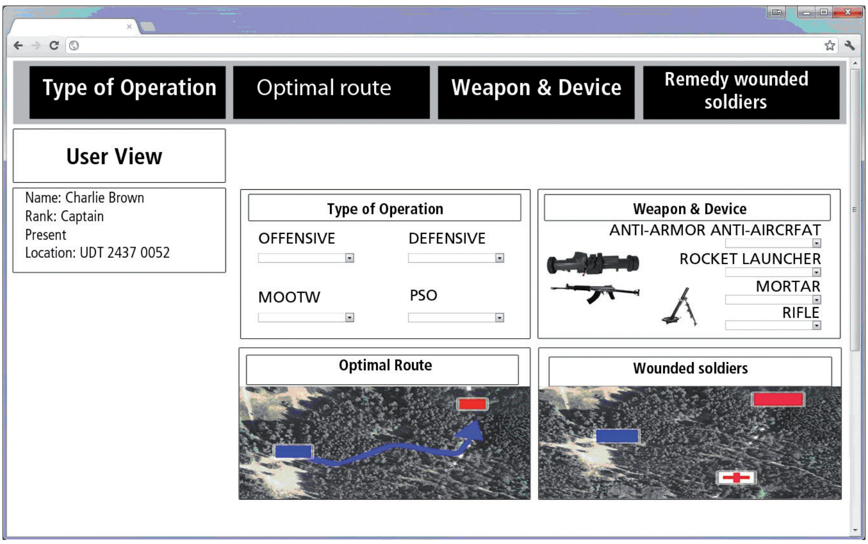

Figure 24. A Graphic User Interface of an FFW.

8. Description of papers produced

The following describes the peer-reviewed papers produced P1–P7.

8.1 (P1) White Force Tracking (Journal of Comm. and Computer)

This paper discusses the means and possibilities to locate impartial entities in a battlespace to reduce collateral damage by utilizing existing COTS-based technology. The paper introduces the term White Force Tracking and links it to the same environment together with Blue Force Tracking. A similar BFT-system has been introduced in [96]. WFT is understood to cover the members of non-governmental organizations, representing both impartial and neutral entities in warfare and conflict contexts. Issues such as whether or not neutral forces want to be tracked fall outside of the scope of this study.

Asymmetric warfare sets more challenges compared to traditional warfare. This paper also introduces the challenges related to identifying the Point of Interest (POI) in a battlespace. It is essential to define the POI early enough as an enemy (red), own (blue), or neutral, White Force. Before the execution of weapon systems, the commanding officer and single warfighter has to be in control of the given situation to reduce incidents of fratricide. In case the POI is identified as an enemy, the decision to use force has to be made rapidly to neutralize the enemy.

Particularly in peace supporting operations, peace forcing operations, and in military operations other than war, the situation setting varies from riot control to pre-war situations in an unpredicted pace. Once the use of soldier tactical mission systems increase, Blue Force casualties become rare and Red Force casualties occur more quickly with the increase of the technological capabilities of the squad equipped with tactical mission systems, as shown in [58]. This study introduces a few technical principles and methods available for locating different types of White Force entities while there is a full-blown armed conflict taking place in the vicinity. Relevant papers produced earlier concentrate on the significance of SA gained via using a tracking system, see [96], and highlight the importance of combat identification by introducing means for solving the problematic challenges in a battlespace, as widely discussed in [155].

Traditional positioning and location services can be reached via Global Positioning System (GPS)-locators, as described in [111], and mobile phones. An example of an exceptional COTS-based tracking service utilized by Finnish hunters for the past two decades is the

Tracker, an application that uses sms-messages and resorts to location satellite services. Systems are reliable and used in domestic company attack exercises with success. Tracker-systems weigh only a few hundred grams including the batteries.

The described Tracker-system is a versatile tool for training purposes and especially after action reports. The significance of after action reports are pointed out in [86]. Figure 25 describes the picture capturation of a computer screen display while a company attack exercise was carried out.

Figure 25. Location data of different war-gaming parties (Blue and Red Force) presented on a laptop screen (S1-5; K1-K5).

One of the solutions used for measuring the location is the integrated navigation system consisting of GPS and Dead Recon Module (DRM) developed in the Force XXI Land Warrior (FXXI LW) program, discussed in [102]. Furthermore, Land Warrior program discussed in [112] pointed out the significance of navigation and wearable computers. The request of navigation skills in urban territory is identified, see [149], which represents an integrated navigation system for the dismounted soldier. The DRM operates from 2 to 5 volts and consumes power for approximately 0.5 watts, see [102]. Today the DRM weighs the 39 grams and the module is to be attached on top of a soldier's shoe. Once the DRM has been calibrated and is supported by a grid filter, the location accuracy is around 2,36 % in uniform terrain but in woodlands location accuracy is nearly doubled (4,9 %), as discussed in [102]. As described in [102], the required horizontal accuracy is 2 percent in a distance traveled in benign conditions and within 5 percent in a distance traveled through rough terrain (more difficult to maintain consistent stride).

As indicated by the cases discussed, an impartial White Force can be located and thereby instances of fratricide and impartial casualties may be minimized together with improving the efficiency of the friendly troops to facilitate success in a battlespace. P1 indicates that some of the existing location methods can be utilized to improve the possibilities to track an impartial entity in a battlespace. Already existing COTS-based location solutions are functional and fairly reliable.

As for the data transmission, the collected data have to be forwarded to the location services centre, which is often based in the same premises as the headquarters. Warriors transmit raw location data and receive purified and refined location information, including the precise location of the White Force. This represents an essential means to collect and share the gained data. The purpose for this is threefold: gaining precise SA data, reducing instances of fratricide, and minimizing collateral damage. As indicated in [151], the role of a personal communication device must not be underestimated.

To collect data on the ground, radio frequency identification-tags can be used. The methods in combat identification can be either active or passive. Unmanned vehicles and robots can be exploited in gathering data with these devices. One of the solutions utilized can be wireless sensor networks. Coded cellular telephones may be used as identification means. One of the oldest systems available is radio frequency -based identification. The identification device consists of a transmitter and the receiver elements, the former based on laser, the latter on a radio frequency system. Warriors can be equipped with the described personnel identification system. The principle is illustrated in Figure 26.

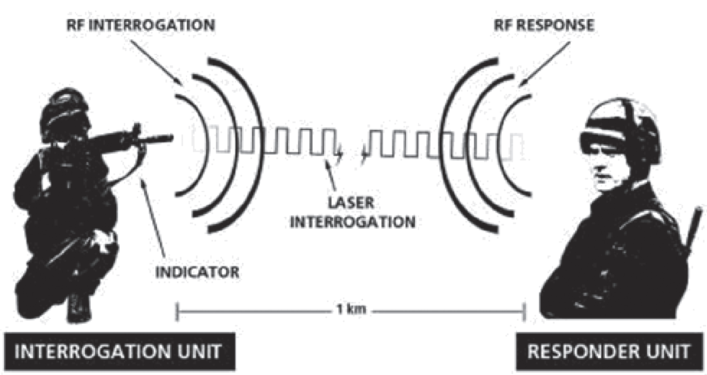

Figure 26. The identification process of a dismounted warrior based on RF interrogation, see P1.

Understandably, the utilization of the existing technology has to be re-evaluated and thoroughly selected solutions have to be exploited at least to some extent to reduce unnecessary destruction in a battlespace. There are three possible location solutions which are based on hybrid solutions: 1) the identification-vest and a wrist-module and an active identification-tag, 2) the RF-identification and a cellular telephone, and 3) the dead recon module and a tracker system. By selecting two different devices from each of these alternatives, it can be ensured that at least one of the chosen devices remains functional at a given point in time. This approach facilitates the location of White Force representatives and can reduce the possibility of fratricide and impartial casualties. Table 4 gives an example of possible location devices based on existing COTS-products.

Solution	Benefits	Handicaps and limitations	Cost High / medium / low	Reliability High / medium / low	Usability High / medium / low
RF-identification	Reliable	Terrain and distance	low	high	high
RFID-tag	Reliable	Terrain and distance	low	medium	medium
Cellular-phone	Reliable	Terrain, distance and relaystation	low	medium	medium
I-cellular-phone	Versatile	Terrain, distance and relaystation	medium	medium	medium
ID-Vest and wrist-module	Secure, reliable	Terrain and distance	low	high	high
Tracker	Reliable	distance, depending on GPS-satellite	low	high	high
Road Track 3.3	Reliable	distance, depending on satellite	medium	high	medium
Dead-Reckoning-Module (DRM)	Reliable, indoors usability	fluctuation	low	medium	medium

Table 4. Different types of location devices suitable for military environments and crises management environments.

Although location devices are indispensable in location services, it must be pointed out that a reliable network system remains crucial. Ad hoc networks evolve and unmanned devices loaded with sensors fill the data gaps in a battlespace while real time requirements are to be met together with QoS. White Force representatives have to be equipped with a trustworthy location device to reduce instances of fratricide and minimize collateral damage by resorting to a reliable network system.

8.2 (P2) Computer-Aided Warriors for Future Battlefields (ECIW2009)

This paper concentrates on the future dismounted infantry warrior and introduces a new way of thinking about how the concept of an FFW should be designed. This involves taking into account Systems engineering since an FFW represents an SoS of a complicated combination comprising computers, devices, and a human being. P2 categorizes the FFWs on the basis of their respective task-levels. In battlespace contexts, the three task-based warrior levels are 1) Basic Warrior, 2) Readiness Brigade Warrior, and 3) Special Forces Warrior. This warrior definition draws on each warrior's training level and thus on his C^4I^2SR-level, see also P7. Moreover, the significance of a Personal Computer (PC) is discussed, as is the human interaction with COTS built UVs highlighted, see [8]. Personal computers and UVs can be seen as tools used in a future battlespace.

P2 argues for the efficiency of the hierarchy-based warrior system instead of the principle of equipping all the FFWs with the newest COTS gear. P2 demonstrates that in human machine interface -based warrior solutions the key relationship is between the different warrior levels and proposes that the FFW is based on the three levels of production line warriors equipped with precise, task- and level-dependent gear. Furthermore, P2 discusses the interconnectedness of the trained warriors and their gear in the light of the three warrior levels.

Equipping and training warriors is a time- and money-consuming process, which means that it is useless and too expensive to equip each warrior with top-gear. Thereby system requirements and system engineering provide the tools for determining the need of the suitable tools for C^4I^2SR-environment at each warrior level. This issue is strongly linked to net centric operations. In order to increase situation awareness at each warrior level, versatile and optimized network solutions have been suggested. Computer-aided warriors utilize all the means available to enhance their SA to complete the mission tasked with minimum casualties if they are equipped with latest tactical gear, as discussed in [58].

There are some new elements in the three levels of an FFW, namely, the location services offered by BFT and other real-time services. As evident, computers need to be present at all warrior levels but their numbers and performance differs depending on the warrior level. Thus the higher the level, the more computers with improved performance are necessary as aids or tutoring devices when choosing and calculating between different courses of actions. Because warriors carry out their tasks in a battlespace in a constantly changing environment and at varying threat assessment levels, computers are utilized as aiding in mission planning and various evaluations possesses. This asks for an ever improved SA, which can be gained via blue force tracking and voice over blue force tracking (one channel is used for voice and another for blue force tracking data), see [32]. These systems provide leaders with vital information in helping them to make informed decisions. Mission efficiency has to be improved regardless of the smaller units used in dismounted operations, since these units require a great degree of flexibility and reliability in order to obtain their set objectives.

Several FFW-projects are currently under way to improve rapid decision-making in hostile environments. One example of these is a joint human-computer cognitive system to support rapid decision-making to fulfill the dismounted warrior needs. In addition, location services provide essential information for warriors' SA, especially in military operations in urban terrain and indoors. The following Table 5 features the estimated masses of C^4I^2SR -gear planned for future warrior concepts, see [47].

Components of subsystem	Weight in kg / device	Company Commander	Platoon / squad Leader /kg	Warrior /kg
Weapon subsystem	0,64	0,64	0,64	0,64
Helmet	0,89	0,89	0,89	0,89
PCIE	1,09	1,09	1,09	1,09
Communications	0,75	0,75	0,75	0,75
CSS (Computer/Master Hub System)	1,9	1,9	not using	not using
Fusion 1,0	0,61	0,61	not using	not using
Navigator	0,62	0,62	0,62	0,62
Computer	0,67	0,67	not using	not using
Soldier Contor Unit	0,47	0,47	0,47	0,62
Pan Cable set	0,47	0,47	0,47	0,47
Pan Cable set	2,04	2,04	2,04	2,04
TOTAL (kg)	10,13	10,13	7,62	7,62

Table 5. Components and masses of the Land Warrior Dismounted Battle Command System.

P2 introduces the warrior's electronic skeleton, which can be used as a planning tool. Since a warrior represents an SoS, the designing of an optimally functioning warrior mirrors the electronic skeleton, a system platform. This system platform has to be light, versatile and modular, since once a part of a system breaks down, a quick removal or replacement of this part is crucial. The structure of the electronic skeleton is visualized below in Figure 27.

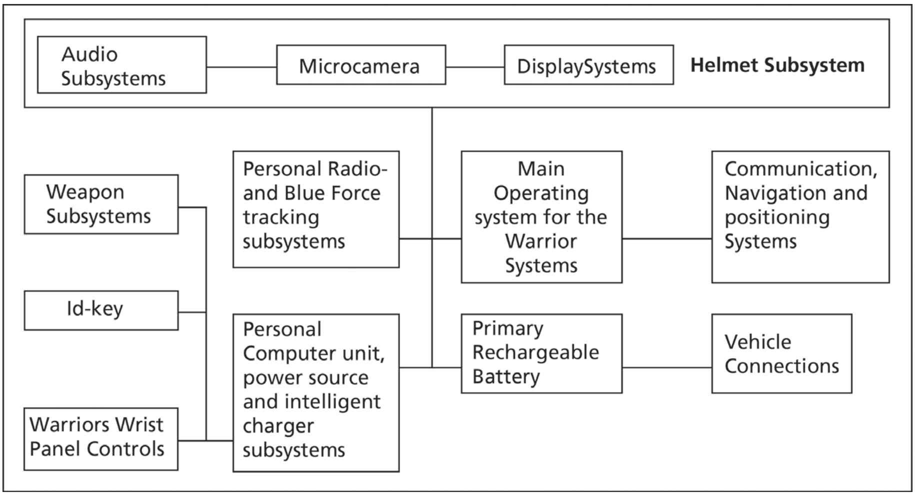

Figure 27. A Warrior's Electronic Skeleton, the system platform.

P2 suggests that contrary to earlier discussions based on the assumption that the efficiency of an individual infantry warrior equals the amount of gear warrior is embedded with, this is not the case. The desired level of efficiency can be reached via careful planning of system requirements. Thus it becomes possible to optimize the performance of a warrior who comprises a group of heterogeneous systems.

P2 discusses how the optimal performance of a warrior draws from maximizing each warrior's efficiency depending on the different task and training levels. This is done by making a match between the composition of warriors at varying task and training levels and the custom-designed electronic skeletons, the system platforms. Earlier studies have not adopted this particular perspective of combining the level of training and the gear. Instead the focus of those studies has been on the amount of gear applied on the different platforms.

As outlined earlier, warriors have to be designed according to their task-based niche. The higher the level of the warrior, the more artificial intelligence can be integrated as part of the systems. Besides, the higher the level of the warrior, more Unmanned Vehicles can be integrated in the warrior equipment and for his use. This means that the workload of each warrior level is predetermined according to the training level. This in turn leads to the different predefined task-based roles of warriors and computers at each training level. In an FFW the embedded computer can be a master, an assistant, or a slave, depending on the level it is located at. Thus, a warrior can be seen in a key role in low level operations, and acting as a node or sensor in NCOs. Thereby each warrior serves as a sensor, gathering, forwarding and receiving data.

The demands for the system design can be seen as demands for the key elements (platform, communication, energy, programming, automatic modes, and alternative modes). Computers have to be ruggedized and robust to match the battlespace requirements once their role is versatile, and the system has to be mobile; the human machine interface needs to be easily taught and easy to use. To cut costs, COTS-products should be disposable and expendable. The computerized systems have to be quickly and remotely reprogrammable and they have to be versatile for different platforms. The FFW concept can be understood as an SoS. The primary focus has to be on the definition of the interoperability and integration properties of the SoS similarly as interoperability is needed in complex systems. Integration of systems is essential and therefore the key is a common language that a given system's all components can speak, for example, Extensible Markup Language. As [97] points out, the most common implementation of SOA is web services based on XML and SOAP.

A computer can be adopted at different warrior levels in different roles: It can be mounted to clothing or on the wrist, for example. The higher the level of a warrior, the more a computer is seen as an assistant. In contrary, the lower the level, the more the computer forwards tasks. As presented in Figure 28, 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 28 below. This process increases warrior efficiency, minimizes fratricide and increases a commander's SA.

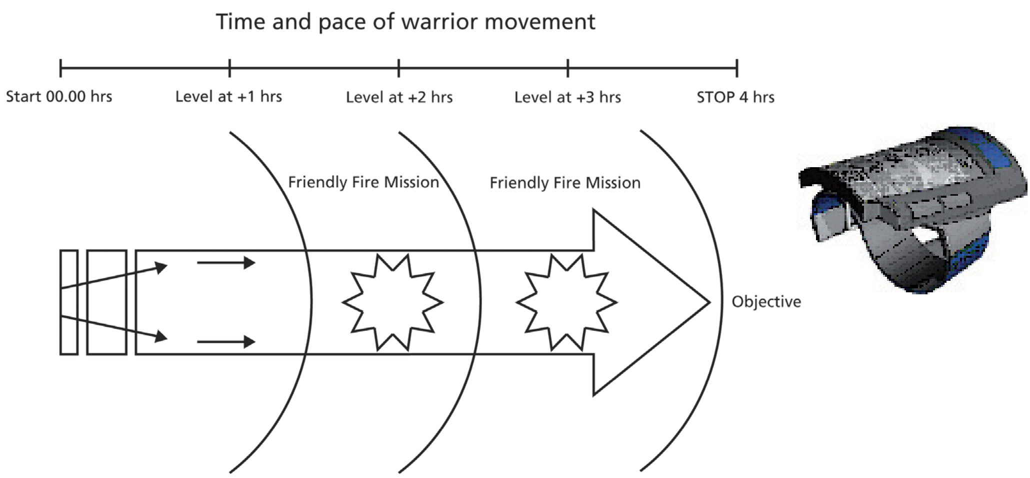

Figure 28. The principle of computer-tasked pace of movement (r) and a wrist module (l).

P2 proposes a practical view on how to equip an FFW and does this by discussing examples featuring the product line warrior based on three warrior levels. An FFW's gear has to be designed to meet the requirements set by a future hybrid battlespace. Therefore, warrior equipment must be versatile and modular. Moreover, remotely controlled UVs serve as tools to improve SA and BFT, and may thereby facilitate mission success, as does the voice over blue force tracking, see [32]. In the future, the number and nature of different human machine interfaces is likely to increase. Effect-based thinking and systems engineering serve as the tools to be deployed to achieve the ultimate goal: an optimally functioning effective FFW at all the command levels in all potential battlespace environments. Remotely controlled UAVs can act as an assisting tool in tracking and monitoring, as discussed in [39]. They can enhance SA, BFT, thereby enforcing the probability of success in missions, even when operating beyond line-of-sight, see [32].

8.3 (P3) Interfacing Collaboration and Command Tools for Crises Management Military Command and Control Systems (Int J. of Electronic Security and Digital Forensics)

This paper explains the possibilities of Command and Control tools in the military environment and crises management environment, as discussed in [63].

The existing SA-tools are understood rather as tools for information distribution than tools for command and control, see [134], which introduces the concept of geographical based Situational Awareness concept. P3 focuses on traceable and sophisticated C^2-tools for tasking and follow-up applicable in a military environment and crises management environment, since current collaboration tools lack the interfaces for C^2-tools and do not support resource scheduling as discussed in [53]. P3 proposes interfaces that crises management collaboration tools should support as part of the military C^4I^2SR system to reduce collateral damage, and carry out joint operations with the assistance of a tool that could improve collaboration, see [33]. The introduced system in P3 aims at a successful SoS based on trusted entities that will perform commanded tasks in a trustworthy manner in a given timeframe. This paper also introduces managing processes in a military environment and crises management environment as business processes.

As P3 points out, the present networking tools used to gain improved SA and to perform common tasks lack the military RM and trust among cooperative entities. Besides, the tools used lack the traceability of a given task and a real-time reporting tool that indicates when a task has been completed. Furthermore, the tools for authentication, authority and security fail to function optimally. P3 introduces a way to tackle the problem of enhancing the performance of collaboration tools in crises management environment, see [125]. P3 discusses, where the division layers through organizational boundaries are and how it is possible to merge an organization with given service producers. It also examines how to connect the varied communication protocols used to the existing network system and utilize the pre-defined collaboration tools and to ensure a controlled process of command and control. Solutions are presented by introducing the military RM, BPs and the Scheduler.

To give an example, in a dismounted company attack the structure of a company attack process can be seen as a chain of planned events. This process requires certain services, which can be allocated to the requester of a service only, if the service is available and within reach. Users of the services can be identified as User Groups (UGs). The user groups request a service, UGs are authenticated, UGs privileges are verified, and after these processes the request is transmitted to the military RM. The military RM then processes the request. Key functions of the military RM can be identified as: 1) to receive the request of a required service, 2) to organize the line of UGs in the correct order depending on the UGs' privileges and situation in a battle space, 3) to check whether or not the service is available and within range, and 4) to provide the UG with an answer, which is either the requested service or a rejection of the request. A typical request can be, for example, a Fire Support Order (FSO). P3 describes the process of an FSO request in an informal SDL diagram, and in a UNITS Table. An example of an FSO is also presented in a simplified message sequence chart and in pseudo code. Typical pre-defined services are also listed and identified. These services can be pre-programmed or provided on-demand.

Correspondingly, at the other end of the process when a task is being received, the process is as follows: The incoming tasks are filtered via various subsystems, which are presented in P3. The given task is passed through authentication, security policy, acceptance policy, willingness and understanding policies, and finally, the execution policy. After the acceptance policy (a task is accepted into the system) the task is forwarded to the military RM, which verifies the task and forwards it to the proper and available entity responsible for its execution. This entity then becomes a task performer, responsible for task execution. The solution enables reliable and continuous collaboration, which asks for trust between the entities and coordination on security issues, authority and authentication; this applies also in SOA. Each task has a time-stamp and its own identification and also contains route data to be tracked whenever tracking data are required. Each task is categorized in an urgency class and its execution process is continuously monitored and evaluated. Once a task has been executed, it will be automatically filed as a completed task in the common database, see [46]. Tracking data of the completed task can be retrieved for analyses purposes at any time by the system operator. As for security, an authentication and agreement tool is implemented in the military RM. Before any task is issued to be executed or resources allocated for use, the task or resource request is processed by the system, as described in P3.

The role of the military RM and the Scheduler are central in collaboration and the entities in the battle space are accounted for by placing constraints to the military RM. The function of this constraining element is described in P3. Moreover, the functionality of the military RM with four intermodules as well as the functionality of the Scheduler are described.

Both in military and crises management operations all the entities participating need collaboration to ensure mission success and survivability which asks for tools enabling improved level of communicating, see [33]. If an entity fails to collaborate, it takes a calculated risk to fail. Collaboration requires suitable tools and reliable and ubiquitous network systems, as discussed in [97]. Collaboration is necessary to avoid chaos and waste of resources and instead be able to pool resources for an optimized outcome. The idea for optimizing resources by using a real-time video-streaming social network with mobile devices is presented in [103]. This article offers three results as a contribution for the further development of C^2-tools: 1) a C^2-tool, which enables the use of BP in the command and control process; 2) the military RM, which is a central element of the MSOA in the distributing of limited resources; and, 3) the applying of the BP approach in a military environment along with Military Service Oriented Architecture. These results offer the yet missing attributes for the C^2-tools for both military environment and crises management environment. Combining these elements may enable a successful control for the BP in ME and CME settings. The article introduces the composition of the military RM and the role of a Scheduler, the function of the BP, and highlights the significance of trust and commitment in CME. Trust is needed to gather information of the entities and to ensure tasks are completed in a timely and appropriate manner. Each entity embedded into the C^2-tool environment can contribute added value in SA and thereby intensify the outcome by committing to the ROE and abiding by the set policies.

8.4 (P4) Free Space Optics in the use of the Future Force Warriors (J. of Comm. and Computer)

P4 offers a new angle to the FFW concept, as an FFW is viewed as a data collector rather than a typical warrior or annihilator. P4 introduces combining the concept of Free Space Optics (FSO) and the concept of the FFW. This combining utilizes existing COTS-technology in civilian applications, as described in [93]. The same technology is applicable for military communication systems. FSO requires a free line-of-sight, see [93]. The introduced use cases offer a method for the end users to communicate with the command posts and transmit significant amounts of data for the purpose of computer-facilitated data and sensor fusion executed in higher echelons. FSO technology as a reliable communication means for distributing urgent SA data in high speed and in forms difficult to detect and intercept is described in [30]. Utilizing weapons' laser target pointer as an FSO transmitter modulated with a computer offers a new method for data transmission. The proposed solution satisfies the needs for a high bandwidth communication for the FFWs by being cost-effective, lightweight, reliable, secure, and addressing several threat scenarios involving disturbances in the electromagnetic spectrum, including environmental problems, jamming, and the use of the high power microwaves. So far, the ongoing FFW projects or soldier modernization programs have not yet investigated the use of FSO technology and may thus potentially benefit from it.

Since Very High Frequency (VHF) and High Frequency (HF)-radios can transmit data with low bit rates in a narrow bandwidth, some cable-free high bit rate communication methods, such as FSO-transmission, as described in [82], see [101], are needed. For data collecting purposes, it is preferable that the FFWs send raw data as pictures or frames instead of text or voice messages, since pictures provide detailed, uncorrupted data for analysis and interpretation purposes, methods introduced in [79]. FSO is an optical communication technology that uses light propagating in free space to transmit data from point-to-point by using low-powered infrared lasers, which can also be used for localization purposes, if range and orientation information is available see [2]. In particular, FSO-technology is useful in good weather conditions in military operations in which data providing processes are time-critical as introduced in [56]. FSO-technology can offer a high-capacity, low power per bit ratio with low costs and low operational power, as indicated in [101], and an easy deployment of the system. The narrow laser light-beam transmission improves overall security with encrypted data. The FSO-technique benefits from the antenna gain of an optical telescope, which can be very high, over 60 dB, see [56]. The overall benefits of the FSO include: the ease of deployment, a license-free operation and high bit rates described in [30] (up to 2,5 Gbit), and low bit error rates (BERs), the immunity to electromagnetic interference, full duplex operation, protocol transparency, low energy consumption (transmitter: from 10 mW to 2

Watts), and operational security. As for the disadvantages, the susceptibility to the impacts of the following factors needs to be pointed out: beam dispersion, atmospheric absorption, rain resulting high BERs as described in [36], fog (10–100 dB/km attenuation), snow, scintillation, and pollution in the atmosphere. In addition, the transmission range is moderate, typically 1,3 kilometers.

FFWs' main task involves locating the POIs, collecting relevant data and forwarding these data to the command post for further data mining and for analysis utilizing computers and calculation programs of appropriate types, as introduced in [28]. In the scenario outlined in P4, FSO is utilized as a one-way transmission system. The FFWs use visual sensors together with infrared (IR) and near infrared sensors to accrue data from the designated spots. The main gain from transferring large amounts of raw image data instead of using a traditional way of sending observations as messages, see [28], is that new data processing capabilities make it possible to recognize faces, understand the situation, locate hidden and concealed targets, and look for essential information by means of computation algorithms introduced in [38]. The recognition of an end-user can be based on visual biometrics and the most conventional identification, the computer-assisted recognition of human face, see [99].

The ubiquitous networks and sensor data can assist in detection, recognition, and automatic target classification systems which rely on different target parameters, see [55]. Moreover, the data produced by various multisensors can be utilized in the data refinery process to ease the recognition and identification with the assistance of data fusion processes by resorting to computer-programs designed for data fusion in identifying vehicles, as described in [92]. When using three military target classes, the unknown target recognition accuracy can reach nearly 85%, while at the same time the classification accuracy of known targets remains above 95 %, as indicated in [148]. This enables the use of an automatic target cuer. FFWs can be commanded to collect the missing data on the designated POIs and areas if necessary. This way the data enriching process is constant and productive and, when applicable, i.e. when interpretation services are requested, assisted by SOA. As indicated in [98], face recognition schemes that combine wavelet transform, Support Vector Machine (SVM) and clustering can be exploited in the process of identifying a human being.

In detecting and tracking specific objects in the knowledge-based framework, the use of the SVMs is recommended for the optimal outcome, as described in [98]. When the methods of light detection and ranging are used, SVMs can be used for their overwhelming capability to measure millions of 3D-points in a few milliseconds in varying conditions.

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)

Table 6. The system characteristics of and functional requirements set for the FSO communication solution.

This set of communication requirements reaches a satisfactory functional level. FSO offers high bandwidth up to tens of gigabits. FSO-technology requires sufficient optical visibility conditions for achieving this range but it is reasonable to assume that if FFWs are employed for collecting SA data by optical cameras, it follows that visibility conditions are adequate also for FSO, as discussed in [2]. As indicated in [30], a laser beam is very difficult to detect and intercept and remains immune to electromagnetic disturbances.

FSO-technology offers a secure and reliable means of forwarding a constant flow of data with an adequate transmission rate, but limiting factors related to attenuation due to weather and athmospheric problems need to be studied, as concluded in [123]. Present communication systems at a warrior level are energy consuming and require a lot of training in order to benefit from the system. 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 analysis and data mining programs, resulting in high level data for increased SA. The key function of an FFW is to collect large amounts of SA information and forward these data to the command post for further data analysis. In brief, adopting FSO into 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. FSO can be utilized when using dense wavelength division multiplexing, as introduced in [82]. 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, see [123]. These factors restrict FSO devices' range communication capability to cover approximately a mile in optimal conditions.

8.5 (P5) Tactical Management in Near Real-Time Systems (Cogsima 2011)

Tactical management in near real-time systems focuses on enhancing SA, especially in the chain of command, see [96]. In [64] research was executed to examine a knowledge visualization approach designed to enhance the decision maker's perception, comprehension, and projection of the shared SA. A functional tactical management system can enable quick recovery times and the capability to maintain constant performance in all types of operations. Needless to say, another key function relates to maximizing the performance of the ever reducing resources.

P5 paper presents a new architectural design called Dynamic Battlefield Hierarchy, which is created to keep the chain of command intact even in the most challenging environment. This means presenting a Battlefield Secure Scheduler as a key component in tactical management by creating a SOA-based process to the C^2-system and enabling offline action capability for subnets and individual devices using Dynamic Battlefield Hierarchy. The C^2-system and commanders become thereby able to evaluate a warrior's performance capability by using history information saved during training and combat: details, such as heart rate, sweating, direction of movement. By using this new DBH architectural design, troops can be reorganized automatically after having suffered casualties. Thus the performance of these automatically re-organized troops can be continuously sustained.

P5 introduces an example of a scenario involving a battalion using the Dynamic Battlefield Hierarchy to achieve its set objective. The overall idea of SOA in military environment highlights and emphasizes the notion of process ideology applicable in an army environment described in [49]. And, to create a process based system applicable in MEs, P5 introduces a new component called the Battlefield Secure Scheduler. This component outlines the process view in the form of a schedule and shares sub-processes on varying abstraction levels. The overall process can be executed from the Army Corps via different level Battalion Commanders (BC), company commanders, companies, platoons and down to the single infantry warrior.

This combination of dynamic hierarchy, BSS-processes and abstraction levels can be seen in Figure 29, which describes the overall view of a Dynamic Battlefield Hierarchy.

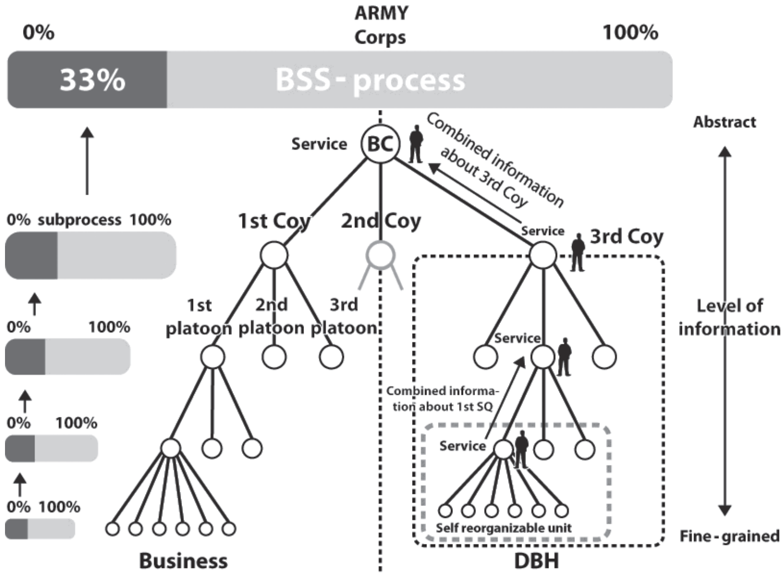

Figure 29. The Dynamic Battlefield Hierarchy.

Necessarily, any given system requires by default value that the connections in, to and from the system are controlled by the system. When it comes to tactical networks, they are usually equipped with small bit rates, and thus any system-wide usage requires a massive amount of networking power, see [153]. The hierarchical units of the Dynamic Battlefield Hierarchy can be seen as a form of subnets within a bigger network system. The idea in this is to simulate the command chain. The network is based on a closed intranet where the terminals create and maintain the outlined hierarchy construction by using web services and universal description, discovery and integration registries used in military communication networks, as discussed in [97].

To illustrate the C^2-system, we can take a look at a basic platoon. The platoon leader uses his squads to meet the set objective and the squad leaders offer the requested services to the platoon leader. All of the platoon leaders offer the set services to the company leader based on the services in their use at the platoon level. At each level it is possible to filter the amount and quality of the information. If a node from the system is lost, if, for instance, a platoon leader gets killed, the system is automatically able to transfer the command of the platoon to the first squad leader.

DBH offers an environment in which the level of knowledge actively changes when transferring from one hierarchy level to another. Each node transmits only combined information. This way we can achieve a hierarchy in which each node features less than six information services. This six-level hierarchy is a common feature in battlespaces, but usually a communication information system lacks this dimension. Moreover, the advantages of the DBH include an efficient and dynamic information distribution network facilitating the C^2-process.

Each node in the DBH transports the messages of the Battlefield Secure Scheduler over the network enabling the node to send a new BSS sheet to all of the child nodes; for example, the Battalion Commander can send a BSS-message to the whole battalion, and a Company Commander is able to send the BSS-message only to his own company. The BSS-message table is not readable as such, but the terminal is able to show the BSS-message table on a map display or in a chronological order.

P5 illustrates how simultaneous operations are aided by the BSS. The Battlefield Secure Scheduler uses two different methods of sharing the calendar: the Pre-Shared Schedule and the Dynamic Schedule Update. This scheduler functions together with the military RM and utilizes SOA as a process in Military Environment settings.

P5 offers an overview of the use of commanders' personal digital assistants during an operation. An operation can be viewed as a BP of a kind. For example, a Battalion Commander receives an attack order from the army corps. The objective of the mission is to conquer a road and to gain superiority in the set region. The attack's process from the starting point to the objective can be explicitly examined afterwards, including the SA function and changes in the battle order by indicating the paths of each company's attack as displayed on the commander's PDA-screen. This tool can be utilized both in after action reports and also for training purposes following each mission.

For the purposes of P5, a laboratory test was executed by using Java and web services. This test modeled a company-level unit working with SOA-based services. The purpose of this test was not to assess the BP aspect but rather to take a look at the technology designed to create SOA for the Company-level unit test purpose. To make this construction work, every unit represented a service. The information flow was organized so that a node in the upper hierarchy level combined the information from the lower level and then offered a service onward to upper levels.

In the DBH-system it is possible to filter the information required on and by the upper level. This construction gives the possibility for any service to act as higher level service if necessary. The software remains the same for all the clients. This DBH-system was created in netbeans with Java. The system was based on the web services which were published by using the Glassfish V2 server introducing the two possible modes of an individual node. In this model three possible types of status existed in the hierarchy: leader, non-leader, and these both combined. The hierarchical status changes automatically if the form of the hierarchy tree changes. Two modes of one soldier were possible. Namely, one particular private was able to act as a leader in case a superior node was annihilated.

To sum up, P5 introduces the following issues: first, a new method to automatically recover a chain of command enabling a military commander to concentrate on leading his troops. Second, the resulting key outcome involves improving SA in a battlespace with SOA thereby directly facilitating the decision making process of battlefield commanders. Third, this tactical management system with its new components (e.g. Dynamic Battlefield Hierachy and Battlefield Secure Scheduler) offers Battlefield Commanders a versatile tool to execute maneuvers as BPs. To enable simultaneous operations, the challenge is solved by embedding the new element named Battlefield Secure Scheduler. This component uses two different methods of a sharing calendar, namely Pre Shared Scheduler and Dynamic Schedule Update. The Battlefield Secure Scheduler functions along with the RM and follows the BP approach to MSOA.

To sum up, these new components enable the commander to command and control his troops while the introduced tactical management system accounts for the casualties in the chain of command, enabling the commander to concentrate on the essential. The ensuing strict C^2-chain facilitates optimal battlespace leadership and functions as a monitoring and reporting tool introduced in [63].

8.6 (P6), Enhancing Situational Awareness by Means of Combat-ID to Minimize Fratricide and Collateral Damage in the Theater (ICDT2011)

The notion of the future battlespace has expanded to refer to a battlespace in which commanders rely on SA-tools to perform optimally in their given tasks, see [96]. Especially, in net-centric operations the effective accruing, transmitting and analyzing of data is crucial in emergency mitigations in particular, as discussed in [65]. Warriors participate in operations which may include combat settings as well as counter insurgency actions, peace-keeping operations and disaster relief activities, sometimes simultaneously. In multi-national operations taking place in versatile and hostile environments, it is essential to be able to detect, classify and identify the encountered and targeted objects in a battlespace early enough to reduce unwanted casualties of war. Human casualties can be avoided by replacing humans with robots armed with lightweight weapon as studied in [152]. P6 adopts a meta-analytic approach and examines the current capability of utilized combat identification-systems to minimize fratricide and reduce collateral damage, as described in [155]. This, furthermore, involves introducing means for enhancing the overall situational awareness in the battlespace.

The paper concentrates on Combat Identification, Target Combat Identification (TCID) and shared SA. It emphasizes the means for exploiting Unmanned Aerial Vehicles and Unmanned Ground Vehicles in the processes of data collection and the distribution of near real-time COP to be implemented in Shared SA discussed in [65]. P6 tackles the following three questions: What are the means to locate a warrior by employing the existing CID and SA technology? How to increase SA with the technological solutions available? And, furthermore, how to test these technologies in peace-time settings?

The process of determining the affiliation of detected objects in a battlespace is called target identification, as discussed in [115]. The traditional method of target identification is based on a visual signature of the object of interest. In contemporary warfare target identification is also based on utilizing the electromagnetic spectrum of a target. A properly applied data and sensor fusion can be seen as a means to prevent collateral damage and fratricide. Target identification can be divided into two categories: Cooperative target identification and non-cooperative target identification as discussed in [115]. Cooperative target identification enables 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. Non-cooperative target identification systems include optics, such as thermal weapon sights, night vision goggles, forward looking infrared radar, as well as vehicle and personnel markings, such as joint combat identification marking systems.

Soldier modernization programs are important in enhancing the performance of militaries, see [9]. These soldier modernization programs concentrate on improving and updating dismounted soldiers' equipment and training to gain the best possible SA. As described in [44], true SA only exists in the mind of the human operator. Varying future soldier programs are currently underway along with a series of demonstrations and exercises aiming at minimizing instances of collateral damage and fratricide, whereas the means to increase SA via improved BFT as discussed in [32] and WFT are also in progress. One example of these is a series of Bold Quest exercises carried out in the USA and Europe since 2007. These exercises can be understood as a test-platform for various sensor platforms applied to warriors of different types. In the Bold Quest 2009 exercise, technical initiatives included prototype-level systems to enable aircrews and controllers to exchange position information digitally among friendly ground elements relative to their proximity to potential ground targets. The results indicated improved capabilities in target acquisition and minimized risks and levels of fratricide incidents.

In military operations everything is done to prevent blue-on-blue. Currently, identifying a warrior regardless of the visibility conditions is essential. As evident, 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, as introduced in [155]. In case the identification system does not reply, a human is making the decision to open fire based on the tactics, techniques and procedures. 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, for example, an insurgent tries to function as a member of the White Force. Systems have to be embedded with a sort of anti-theft system, to prevent the system from falling in wrong hands.

The ROE and tactics, techniques and procedures (whether or not to open fire), functions behind the targeting process, deserve a closer look, as described in [114]. The process is known as Detect, Identify, Decide, Engage and Assess, see [115]. Computers can be utilized to calculate the optimum course of actions and tactics, techniques and procedures.

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 has to fight, not to monitor his palm, wrist computer or lap-top. The problems in data distribution are linked to various devices and data in interfaces. Battle management language can be seen as a common language enabler between machines and interfaces along with almost ubiquitous swarms of UAVs [122]. The language in BML has to be understood between all of the machines, computers and computing programs performing inside the networks. Limitations in energy and bandwidth play an important role. 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), as discussed in [157]. Also the hierarchy of a network has to support and enable this communication. In military operations in urban terrain the transmitting and receiving signals of different waveforms simultaneously remains challenging due to the nature of the combat environment, especially indoors, as discussed in [143].

As for increasing SA with the technological solutions available, the purpose of the precisely described Bold Quest exercises is to enhance SA, target identification and methods for minimizing collateral damage and fratricide. A key factor is the efficiency of a warrior, which can be gained via improved SA, BFT and C^4I^2SR see [32]. However, since supplementary gear can never fully substitute human intelligence, a warrior must remain active and alert in the battlespace. Achieving this objective requires testing these technologies in peace-time settings. So far, all the decision-making processes in battlespace settings have culminated in a human being making the final decision to apply combat power, see [114]. In the future, this decision maker's position may be manned by AI. And, needless to say, detailed planning, testing and implementation are necessary prerequisites for all future warrior systems to be successfully deployed by any robotic militaries of the future, as discussed in [72].

8.7 (P7) UAV-based Sensor Networks for Future Force Warriors (Intl. J On Advances in Telecommunications)

P7 describes a future warrior system, presents a Wireless Polling Sensor Network solution, and explains the main use cases of the WPSN concept: road-side bomb detection, location service in built-up areas, and marking a target by Special Operations units. An evaluation of the advantages and disadvantages of the proposed WPSN concept is offered; and a provably computationally secure crypto-protocol between base stations and other nodes, such as UAVs, is presented. The main output of the paper offers WPSN solutions together with Self-Calibrating Pseudolite Arrays (SCPAs) and UVs to attain the maximum performance at all warrior levels.

P7 examines each of the use cases of the WPSN solutions. These solutions involve road bomb detection, location in built-up areas and Special Operations. The results can be defined as answers to questions such as: What is the structure of the WPSN like? What are the main advantages of the WPSN over the WSN? Which are the typical scenarios in which the WPSN can be exploited?

P7 describes the composition and structure of the WPSN, and the two modes in which the WPSN can function. Furthermore, the advantages over the traditional WSNs are survivability of the WPSN system in case of a high number of nodes being removed. The transmission procedure can be coded to improve security. In addition, the transmission protocol can be programmed to transmit data only if the node has something to report. Lastly, since directional antennas emit signals only in the upward direction, the free line-of-sight allows for low energy consumption.

The advantages of Unmanned Vehicles introduce a new angle to the C^4I^2SR -environment as a new sensor and a relay platform see [8]. For example, networks utilizing COTS components mounted on of UAVs add survivability and remove the need for a line-of-sight connection, as described in [62]. Once the UAVs or UGVs are used as swarms, the combat survivability of the system can be increased.

The main use case proposed in P7 is road side bomb detection. The effect of roadside bombs can be avoided once their precise location is known early and precisely enough and a patrol can disarm them. Fixed sensors on the road side monitor the area continuously. A UAV (or a swarm of UAVs forming an ad hoc –network for a more survivable solution) polls the fixed sensors periodically. The adversary has no gain from knowing the polling period, for instance once an hour, since the sensors in any case record any activity in the protected area. The

UAV can be shot down, but that is an offence in itself. The mobile polling nodes (UAVs) follow preprogrammed routes and therefore they know the location of each fixed sensor node. Should a polling node notice that a sensor node is not responding to polling, this means that the sensor node has been removed or disabled by the adversary, or that the sensor node malfunctions. A patrol would then be sent to investigate the issue. The fixed nodes detect activity at the road-side, such as humans or large moving objects. The detection is based on a significant change in the different sensors monitoring changes in the electromagnetic, thermal, or seismic spectrum of the monitored area. As road side bombs are typically placed on the given sites hours or days in advance, the WPSN application does not require real-time reporting to meet the requirements set for data collecting and transmitting.

The WPSN solution can also be utilized in Military Operations in Urban Terrain. GPS-Pseudolites, or SCPAs, have applications in navigation, see [104]. There are two applications of WSPN based on SCPAs. The first one is for inside location purposes: a warrior polls the SCPA stationed on an urban battlefield (roof-tops, perimeters of buildings).

The second one is for guiding precision munition. A well-known fact is that solid concrete bunker-type hard targets cannot be destroyed with the weaponry carried by warriors of Special Forces. The power of the higher echelon has to be utilized. For this purpose, the target has to be marked for the bombs or guided missiles. The idea is to set the SCPAs close to the selected target and measure the distance and direction from this specific spot at the target. This way the place of each SCPA is very precisely measured in relation to other SCPAs and the target, as indicated in [104]. Once this has been done to each SCPA, a swarm of UAVs can be sent on their way to poll the SCPAs and collect the data to be transmitted to the destruction device for preparation purposes, if needed. Pseudolites only answer to the UAVs according to the communication protocol described earlier. Finally, a bomb or guided missile polls the SCPAs while heading towards the target and, based on the collected data, the destruction device is being guided at its target and the target becomes annihilated.

An advantage of the WPSN solution is that 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 UAV through encrypted messages. Thus WPSN responds only after a UAV 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. P7 presents a new crypto-protocol created by Jorma Jormakka based on exchanging One-Time Pads, used between base stations and other nodes of the proposed system. The crypto-protocol has appeared earlier in the departmental preprint series in [75] but has not been published.

FFWs have to remain functional and their gear must to be planned according to FFWs' set tasks. A key factor is the efficiency of a warrior, which can be gained via an improved SA, BFT and C^4I^2SR, see P2. A FFW has to maintain his or her agility and stay active in the battlespace. Furthermore, only part of the gear necessary can be attached. As demonstrated via the use cases, WPSN solutions together with SCPAs and UVs can be utilized to reach improved performance at all the warrior levels. Planning the warriors' gear requires a deep understanding of the operational environments and the requirements set for the performance of an FFW.

The main setting of the WPSN is the Future Warrior system. A warrior's electronic skeleton, shown in Figure 30, is the backbone and platform for implementing the required electronic solutions to be used in a future battlespace. The WPSN is a part of a larger system of communication, navigation and positioning systems.

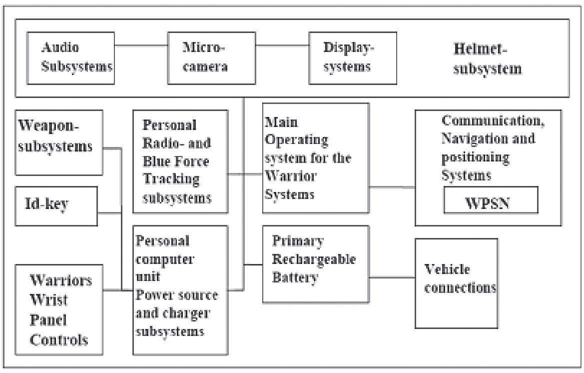

Figure 30. A Warrior's electronic skeleton.

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 and BFT. Warriors have to maintain their agility and remain active in the battlespace; all the gear necessary cannot be attached. The present solutions seen in active use are cumbersome and lack integration. The maximum potential remains unreachable without sensor and data fusion. Militaries are moving towards smaller units while the demands keep increasing. At the same time troops are created for dismounted operations in which a greater degree of flexibility and reliability of battle-proof and robust systems are needed.

The UAV sensor network examined in P7 is still in a design phase and no implementation can be tested. The evaluation of the whole solution can only be based on examining the basic ideas of the concept and determining its strengths and weaknesses. P7 discusses some typical problems and issues that should be considered in any sensor network solution. These issues evaluated include: offered service, coverage issues, operational limitations, performance issues, dependability issues, energy issues, technology development, and possible applications.

The WPSN-solution features many advantages over those of the traditional WSNs. These include that polling can use sensor specific codes and thereby security issues become easier to tackle. 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 are removed. As demonstrated via the presented use cases, WPSN solutions together with SCPAs and UVs can be exploited to reach improved performance at all warrior levels.

9. Future Research

The research questions of the study focus on the possibilities of improving overall FFW performance capabilities. The key for enhanced capability may rest in effectively embedding WPSN, SOA, RM, Scheduler and modeling a military operation as a process similar to the recognized Business Processes. Challenges related to BFT and increased level of SA need to be solved. Furthermore, laboratory and field tests are required. When capabilities related to combat identification and target identification can be significally improved, it may be possible to minimize incidents of collateral damage and fratricide in military operations. The adoption of proper collaboration tools can enhance the level of trust and performance. This is particularly important while operating as part of international task forces.

Funding permitting, apart from conducting applicable tests, more detailed research questions need to be formulated as the practical tests concerning tactics, techniques, and procedures must be performed with the assistance of augmented reality, virtual environment, and simulations. In addition, live-firing exercises are required to test the combat-proof of the systems that are being created.

Haptic interfaces seem to offer new possibilities for controlling various systems. Haptic interfaces can offer new solutions for communication systems in forwarding messages to warriors without intercepting their main mission: to fight. However, the possibilities of communication via haptic interfaces have to be first tested in a simulated environment, then in live-firing exercises, and lastly, in operations executed in a battlespace.

The facilities for an FFW system type of testing have to be carefully planned and prepared. The testing of a new solution or a new system can be extremely expensive. The future studies also require other resources, such as time and personnel.

The electronic FFW skeleton and its communication systems need to be carefully built at each warrior level according to the task requirements and threat assessment analyses. Currently, the solutions available for warriors represent cumbersome systems which lack integration.

An FFW can be understood as a tool in network-centric warfare functioning as a force multiplier. To fulfil the expectations, the timing from the sensor to the shooter has to be minimized. Similarly, incidents of collateral damage and fratricide have to be minimized.

Challenges related to implementing FFW systems are numerous. An FFW has to be fully functional at all designated warrior levels. This means optimization studies related to selected devices of the gear, total mass of the gear and solving the energy and power constraints. Although the amount of electrical devices embedded to warrior gear can theoretically increase the performance of an FFW, still the human capabilities to comprehend vasts amounts of data need to be carefully tested and analyzed. The three-tier categorization of warriors into the levels of Basic Warrior, Readiness Brigade Warrior, and Special Warrior has to be tested in extensive field-trials.

Since an FFW is a platform for electronic systems and combat gear, the obvious challenges related to sustaining energy supply and the overall weight of the embedded gear have to be solved. Communication remains a challence as well. The FFW systems and their true operational performance capabilities have to be tested as described earlier. Figure 31 covers some of the devices, systems and sub-systems that are a part of a dismounted FFW platform.

Figure 31. An FFW as a platform for various systems.

FFWs' PCs' status is dependent on the warrior-level in question: slave, assistant, or master. FFWs' capabilities for collaboration have to be tested together with systems which can enhance resource scheduling and mission planning. Tools with the capabilities of the introduced military RM and the Scheduler are required and need to be tested. The overall objective of planning and designing of an FFW aims at reducing instances of fratricide and collateral damage. The performance of the output of combat effectiveness must be modeled and tested.

Reliable and functional interfaces between a human and a machine have to be developed and tested. This means examining and testing the settings for enhancing improved common operational picture at the commander level and SA at the level of an FFW. Waging war with and against unmanned vehicles has to be prepared for and trained. Controlling machines and communicating in the battlespace requires functional and user-friendly graphical user interfaces. They are also in a significant role in adopting Web Services. An example of a user-friendly graphical user interface is depicted in Figure 32.

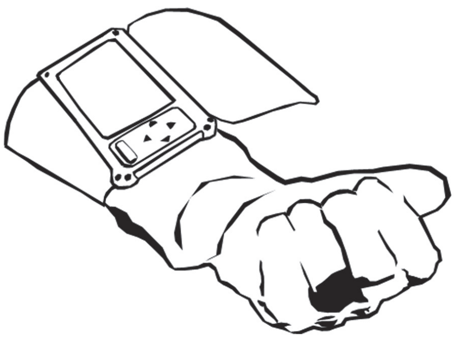

Figure 32. The placement of a user-friendly graphical user interface.

The helmet of an FFW is crucial in the FFW sub-systems: it both protects a user's head and also functions as a sub-system for communication devices and visualization systems. Representing an essential platform for communications systems, the helmet has to be carefully planned. The helmet as a sub-system is depicted in Figure 33.

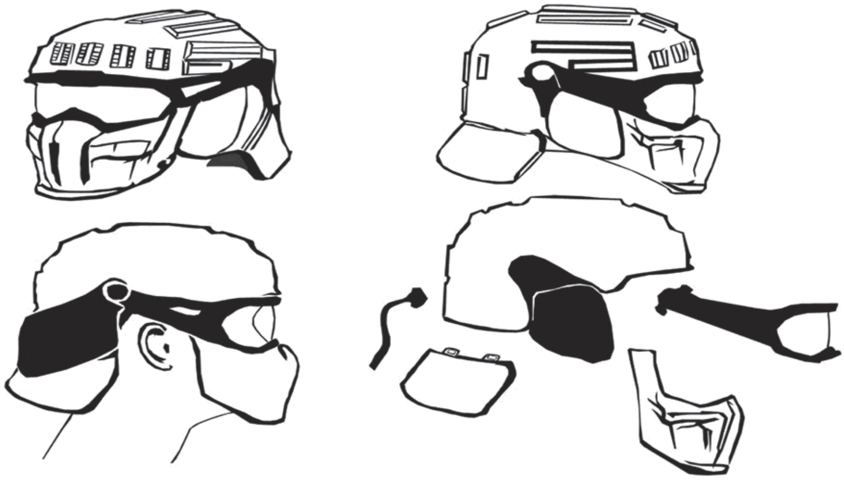

Figure 33. A helmet as an adjustable tailored platform for SA-systems.

To conclude, a need remains for a more effective and versatile FFW. Militaries of the world are downsizing their number of troops while requiring increased performance capabilities of the remaining troops. Versatile tasks along warfighting, including executing humanitarian missions, continue to set new requirements for warfighters and their capabilities. An FFW can be seen as a force multiplier. Therefore an FFW has to be carefully planned, tested and adopted to reperesent an applicable solution to serve as a tool suitable for missions executed in a future battlespace.

10. CONCLUSIONS

In the beginning of this study, the following four research questions were raised:

1) What could be a suitable sensor network tool for current operational situations?
2) How can SOA be used in military settings to improve warrior performance?
3) How can militaries benefit from new communication technology in crises management operations?
4) Which new concepts can be developed to aid in reducing the incidents of fratricide and collateral damage?

The papers produced aim to provide answers to these research questions. The conclusions of this study are:

1) A suitable sensor network tool for battlespace can be the Wireless Polling Sensor Network, as concluded in P7. P7 suggests WPSN solutions which may improve the C4I2SR of an FFW at all levels and indicates that an FFW can receive and transmit more critical information in battlespace by using the proposed WPSN solutions. P7 also describes three scenarios in which WPSN can be utilized to maintain the initiative.

2) SOA can be used in military environments and may improve performance, as indicated in Paper P3. P3 offers three contributions for the further development of C^2-tools: 1) a command and control tool, which enables the Business Process in the command and control process; 2) the military Resource Manager, which is an essential element of the military service oriented architecture in distributing limited resources; and 3) the BP in the military environment along with the MSOA. These results offer C^2-tools yet missing in the ME and CME. Merging these elements enable a successful control of the BP with the assistance of improved C^2-tools.

Paper P5 examines the applying of SOA in a battlespace and presents tactical management in near real-time Systems. P5 describes how present command and control systems lack the automatic level of rearranging the troops' command chain in tactical operations. P5 offers an approach to solving this problem by presenting a new architectural design called the Dynamic Battlefield Hierarchy, which keeps the chain of command intact. Moreover, an essential component of the DBH, a Battlefield Secure Scheduler, is presented.

3) New tools for crises management tools for command and control, and traceability of tasks have been idealized. New communication technology is offered in P4. P4 demonstrates that FSO offers a possible means to transmit large amounts of data to command posts with a

quick wireless set up. FSO also offers an insensitive and reliable means to improve the overall SA in various types of military operations.

Another tool is featured in P6 which offers tools for a functional decision making process via improved capabilities of combat identification and target identification which are currently lacking in the available SA systems embedded with combat identification and target identification systems.

4) New concepts have been developed which may aid in minimizing the incidents of fratricide and collateral damage.

P1 discusses solutions for pinpointing and locating the members of the White Force. These solutions may be functional, reliable and are based on COTS-technologies. Although the required technologies exist, their utilization has to be re-evaluated, and thoroughly selected solutions need to be adopted to reduce unnecessary destruction in a battlespace.

P2 outlines the three-level task-based categorization of FFWs, the autonomous mobile product-line warriors, whose gear must be designed to be light, versatile and modular to meet the requirements of the future asymmetric and hybrid battlespace.

The planning of warrior gear requires a deep understanding of the environment and the demands set on a warrior. A warrior's niche and the nature of his or her missions have to be thoroughly comprehended. Systems have to be planned to be suitable for military personnell in battlespace. FFW systems need to have an indicator informing their status (functional/dysfunctional) and the procedures to replace the malfunctioning or destroyed item has to be carefully planned. The key relies in precise planning based on the defined requirements of warrior systems and subsystems – which must be threat- analyses-based – this may then eventually facilitate enahancing dismounted FFW performance capabilities.

The development of dismounted FFWs aims at creating a warrior system which contributes towards improved capabilities enabling in minimizing the incidents of fratricide and collateral damage. This is brought into being by ensuring that the equipment and systems involved communicate with each other and submit reliable location data. By means of reliable location data and the ability to locate own forces timely and accurately operations can become safer and less damage inflicting.

REFERENCES

[1] Agba, B.L., Gagnon, F., and Kouki, A., Channel Capacity and Second Order Statistics in Tactical Mobile Ad Hoc Networks, *IEEE Conference on Global Telecommunications (GLOBECOM2008)*, Nov. 30 2008–Dec. 4 2008, New Orleans, LO, pp. 1–5, doi 10.1109/GLOCOM.2008.ECP.120.

[2] Akella, J., Yuksel, M., and Kalyanaraman, S., A Relative Ad hoc Localization Scheme using Optical Wireless, *2nd International Conference on Communication Systems Software and Middleware*, 2007 IEEE Press, pp. 1–8, doi 10.119/COMSWA.2007.382580.

[3] Al-Abri, D., and J. McNair, Improving Localization Accuracy in Wireless Sensor Networks using Location Verification Feedback, *in Proceedings of IEEE International Conference on Military Communications (MILCOM) 2007*, 29–31, Oct. 2007, Orlando, FL, U.S.A., pp. 1–7, doi 10.1109/MILCOM.2007.4454844.

[4] Alberts, D.S., Garstka, J.J., and Stein, F.P., *Network Centric Warfare, Command and Control Research Program (CCRP) Publication Series*, 6th printing, April, 2005, ISBN 1-57906-019-6.

[5] Ali, S. R., Wexler, R., and Hoffmann, R., Soldier Network Extension (SNE) On-The-Move Satellite Communications (SATCOM) for Army Tactical Battalion-Level Network Healing and Thickening in *Proceedings of IEEE International Conference on Military Communications (MILCOM) 2007*, Orlando, USA, pp.1–5, 10.1109/MILCOM.2007.4455035.

[6] Allen, J. Duong, Q. and Thompson, C., Natural Language Service for Controlling Robots and other Agents, *in Proceedings of IEEE conference in Integration of Knowledge Intensive Multi-Agent Systems (KIMAS) 2005*, doi 10.1109/KIMAS.2005.1427150, pp. 592–595.

[7] Alsharabi, N., Li R.F., Zing, F., and Ghurab, M., Wireless sensor networks of battlefields hotspot: Challenges and solutions, *6th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks and Workshops, (WiOPT 2008)*, 1–3 April 2008, Berlin, pp. 192–196, doi 10.1109/WIOPT.2008.4586064.

[8] Appelqvist, P., Knuuttila, J., Ahtiainen, J., Development of an Unmanned Ground Vehicle for task-oriented operation – considerations on teleoperation and delay, *in Proceedings of Advanced Intelligent Mechatronics (AIM), 2007*, pp. 1–6, 10.1109/AIM.2007.4412567.

[9] Baddeley, A., Soldier Modernisation Programmes, *Journal of Military Technology, Special Issue 2011, Soldier Technology,vol XXXV*, pp.10–22, ISSN 0722-3226.

[10] Bahrepour, M., Meratnia, N., and P. Havinga, Sensor fusion-based Event Detection in Wireless Sensor Networks, *in Proceeding of Mobile and Ubiquitous Systems, Networking Services, (MobiQuitous2009)*, 13–16 July 2009, Toronto, Ont., pp. 1– 8, doi 10.4108/ICST.MOBIQUITOUS2009.7056.

[11] Barber, D., Davis, L., Kemper, D., Smith, P., and Nicholson, D., Collaborative human robot interactions in combined arms operations, *IEEE Conference on International Symposium on Collaborative Technologies and Systems, 2007*, pp. 88–92, doi 10.1190/CTS.2007.4621742.

[12] Behzad, A., Rubin, I., and Mojibi-Yazdi, A., Distributed power controlled medium access control for ad-hoc wireless networks, *Proceedings of Computer Communications (CCW2003)*, 20–21 Oct. 2003, Los Angeles, CA, USA, pp. 47–53, doi 10.1109/CCW.2003.1240789.

[13] Bellotto, N., and HU, H., Multisensor data fusion for joint people tracking and identification with a service robot, in *Proceedings of IEEE conference on International Conference on Robotics and Biometrics (ROBIO), 2007*, pp. 1494–1499, doi 10.1109/ROBIO.2007.4522385.

[14] Bennett, B., Hemmings, B., and Hamilton, B., Operational Considerations of Deploying WiMAX Technology as a Last-Mile Tactical Communication System, in *Proceedings of IEEE International Conference on Military Communications (MILCOM2006)*, Washington, DC, U.S.A., 23–25 Oct. 2006, pp. 1–7, doi10.1109/MILCOM.2006.302298.

[15] Bhattacharyya, A., Mazumdar, C., and Saraswat, V., A Real-Time Robust Decision Support System for Network Centric Warfare, in *Proceedings of the 8th European Conference on Information Warfare and Security, ECIW2009*, Braga, Portugal, 6–7 July 2009, pp. 9–19.

[16] Boggia, G. Camarda, P. Grieco, L., and Zacheo, G., Toward Wireless Networked Control Systems: An Experimental Study on Real-time communications in 802.11 WLANs, in Proceedings of *IEEE International Workshop on Factory Communication Systems (WFCS 2008)*, 21–23 May 2008, Dresden, pp. 149–155, doi 10.1109/WFCS.2008.4638711.

[17] Bolstad, C., and Endsley, M., Tools for Supporting Team SA and Collaboration in Army Operations, *Advanced Decision Architecture Conference*, May 2003, College Park, MD, pp. 1–6.

[18] Bose, P., Zimdars, A., Carrier, A., Pandya, J., Quilling, M., Slavin, V., and ElBatt, T., Network utility maximization-based Mobile Ad hoc Networking, *IEEE Conference on Military Communications, 2008, (MILCOM 2008)*, 16–19 Nov. 2008, San Diego, CA, pp.1–7, doi 10.1109/MILCOM.2008.4753582.

[19] Brown, D., Coyne, J.T., Stripling, R., Augmented Reality for Urban Skills Training, *Virtual Reality Conference*, 25–29 March 2006, pp. 249–252, doi 10.1109/VR.2006.28.

[20] Brown, W.W., Marano, V., MacCorkell, W.H., and Krout, T., Future combat systemscalable mobile network demonstration performance and validation results, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2003)*, 13–16 Oct. 2003, Vol. 2, Pages: 1286–1291, doi 10.1109/MILCOM.2003.1290412.

[21] Cao, Y., Klamma, R., Hou, M., and Jarke, M., Follow Me, Follow You – Spatiotemporal Community Context Modeling and Adaptation for Mobile Information Systems, *9th International Conference on Mobile Data Management (MDM '08)*, 27–30 April 2008, Beijing, pp.108–115, doi 10.1109/MDM.2008.30.

[22] Capi, G., A New Robotic Platform for Human Robot Interaction, Proceedings of *2009 IEEE International Symposium on Assembly and Manufacturing*, 17–20 November 2009, Suwon, Korea, 316–320, doi 10.1109/ISAM.2009.5376951.

[23] Chakrabarti, S. and Mishra, A., QoS Issues in Ad Hoc Wireless Network, *IEEE Communication Magazine, Vol. 39, Issue 2, 2001*, pp.142–148.

[24] Chang, C-Y. Shih, K-P., and Lee, S-C. ZBP: A Zone-based Broadcasting Protocol for Wireless Sensor Network, Wireless Personal Communications, 2004, Journal of *Springer Netherlands, Vol 33, Number 1*, pp. 53–68.

[25] Chaumette, S., Laplace, R., Mazel, C., Godin, A., Secure Cooperative Ad Hoc Applications within UAV Fleets, *IEEE Conference on Military Communications Conference (MILCOM 2009)*, 18–21 Oct. 2009, Boston, MA, pp. 1–7, doi 10.1109/MILCOM.2009.5379819.

[26] Cheng, C-M., Hsiao, P-H, Kung, H. T., and Vlah. D., Transmit Antenna Selection Based on Link-layer Channel Probing, in Proceedings of *IEEE Conference on World of Wireless, Mobile and Multimedia Networks*, 18–21 June 2007, Cambridge, MA, U.S.A. pp. 1–6, doi 10.1109/WOWMOM.2007.4351703.

[27] Chevli, K., Kim, P., Kagel, A., Moy, D., Pattay, R., Nichols, R., and Goldfinger, A., Blue Force Tracking Network Modeling and Simulation, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM 2006)*, 23–25 Oct. 2006,pp. 1–7, doi 10.1109/MILCOM.2006.302050.

[28] Chien, C-H., Target acquisition using Natural Feature Image Recognition, 2009 in Proceedings of *IEEE Conference on Aerospace*, pp. 1–7, doi 10.1109/AERO.2009.4839575.

[29] Chim, Y-C., Seah, K-W., Sim, S-L., Khoo, K.-L. Lee, Y.-S. Foo, Y-C., and Lai, YC., Employing Ad-Hoc Networking with Aerial Communications Nodes for Wireless Tactical Experimentation, in Proceedings of *IEEE Conference on Military Communications (MILCOM2006)*, 23–25 Oct. 2006, Washington, DC, pp. 1–7, doi 10.1109/MILCOM.2006.302028.

[30] Chlestil, C., Leitgeb, E., Schmitt, N., Sheikh Muhammad, S., Zettl, K., and W. Rehm, Reliable Optical Wireless Links within UAV Swarms, in Proceedings of *Transparent Optical Networks*, 18–22 June, 2006, Nottingham, Great-Britain, pp. 39–42, doi 10.1109/ICTON.2006.248491.

[31] Costa, P.C.G., Chang, K-C., Laskey, K.B., and Carvalho, R.N., A multi-disciplinary approach to high level fusion in predictive situational awareness, in Proceedings of *12th International Conference on Information Fusion, (FUSION '09)*, 6–7 July 2009, Seattle, WA, pp. 248–255, Print ISBN: 978-0-9824-4380-4.

[32] Cummings, B., Zimmerman, T., Robinson, B., and Snyder, M., Voice over Blue Force Tracking, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM 2006)*, 23–25 Oct. 2006, Washington, DC, pp. 1–5, doi 10.1109/MILCOM.2006.302173.

[33] Damian, D., Marczak, S., Dascalu, M., Heiss, M., and Liche, A., Using a Real-Time Conferencing Tool in Distributed Collaboration: An Experience Report from Siemens IT Solutions and Services,IN Proceedings of *Fourth IEEE International Conference on Global Software Engineering (ICGSE 2009)*, 13–16 July 2009, Limerick, pp. 239–243, doi 10.1109/ICGSE.2009.31.

[34] De Rango, F., Fazio, P., and Marano, S., Utility Based Predictive Services for Adaptive Wireless Networks with Mobile Hosts, 2009, *IEEE Transactions on Vehicular Technology, vol 58, issue 3*, pp. 1415–1428, doi 10.1109/TVT.2008.924989.

[35] Dekker, A., A Taxonomy of Network Centric Warfare Architectures, http://www.carlisle.army.mil/DIME/documents/SETE_Dekker.pdf, accessed on July 12, 2009.

[36] Desai, A., and S. Milner, Autonomous Reconfiguration in Free-Space Optical Sensor Networks, *IEEE Journal on Selected Areas in Communication, vol 23, issue 8, 2005*, pp. 1556–1563, doi 10.1109/JSAC.2005.852183.

[37] Dhanani, S., Arseneau, J., Weatherton, A., Caswell, B., Singh, N., and Patek, S., A Comparison of Utility-Based Information Management Policies in Sensor Networks, in Proceedings of *IEEE Conference on Systems and Information Engineering Design Symposium, (SIEDS2006)*, 28–28 April 2006, Charlottesville, VA, pp. 84–89, doi 10.1109/SIEDS.2006.278718.

[38] Do, Y., Dividing an image blob of two connected people using shape information, *International Conference on Wavelet Analysis and Pattern Recognition (ICWAPR2008)*, pp. 152–157, doi 10.1109/ICWAPR.2008.4635767.

[39] Dobrokhodov, V.N., Kaminer, I.I., Jones, K.D., and Ghabcheloo, R., Vision-based tracking and Motion Estimation for Moving targets using Small UAVs, *Proceedings of the 2006 American Control Conference Minneapolis*, June 14–16, Minnesota, USA, pp. 1428–1433, doi 10.1109/ACC.2006.16564418.

[40] Domingo, A., Wietgrefe, H., and Rico, M.A., A COTS based Testbed to Develop Mission Tailored Solutions: Versatile Communications Backbone Network, *3rd International Conference on Communities, (TridentCom 2007)*, 21–23 May 2007, Lake Buena Vista, FL, pp. 1–7, doi 10.1109/TRIDENTCOM.2007.4444662.

[41] Durresi, M., Durresi, A., and Barolli, L., Hierarchical Communications for Battlefields, in Proceedings of *21st International Conference on Advanced Information Networking and Applications Workshops, 2007, (AINAW '07)*, Niagara Falls, Ontario, Canada, 21–23 May, vol 2, pp. 690–695, doi 10.1109/AINAW.2007.198.

[42] Durresi, A., Durresi, M., and Barolli, L., Secure Mobile Communications for Battlefields, *International Conference on Complex, Intelligent and Software Intensive Systems, (CISIS 2008)*, 4–7 March 2008, Barcelona, pp. 205–210, doi 10.1109/CISIS.2008.125.

[43] Dusseau, D., and Brock, C., Network centric interoperability – using a variable message format (VMF) based data-link to improve situational awareness and close air support (CAS), *Aerospace and Electronic Systems Magazine, Sept. 2004, vol 19, issue 9*, pp. 8–13, doi 10.1109/MAES.2004.1346919.

[44] Endsley, M.R., and Connors, E.S., Situation awareness: State of the art, in Proceedings of *Power and Energy Society General Meeting – Conversion and Delivery of Electrical Energy in the 21st Century*, 20–24 July 2008, Pittsburg, PA, pp. 1–4, doi 10.1109/PES.2008.4596937.

[45] Erl, T., Service-Oriented Architecture, Concepts, Technology, and Design, Pretience Hall PTR, 02 August 2005, ISBN-10: 0131858580.

[46] Erwin, S., Army to Deploy Web-Based Intelligence Network, National Defence / October 2005, http://www.nationaldefensemagazine.org/archive/2005/October/Pages/army_to3094.aspx, accessed on 14th of February, 2011.

[47] Erwin, S., "Army Land Warrior" Not Yet Ready For War, Gears Up for Next Tryout , National Defence / March 2006, http://www.thefreelibrary.com/Errata.-a0145836357, accessed on 14th of February, 2011.

[48] Evbuomwan N.F.O., Sivaloganathan S., and Jebb A., A Survey of Design Philosophies, Models, Methods and Systems, *Proceedings IMechE Part B: Journal of Engineering Manufacture*, Vol. 210, No. B4, 1996, pp. 301–320.

[49] Farroha, B., Farroha, D., SOA as a catalyst to empower the Warfighter through improved enterprise data access over the GIG, *3rd Annual IEEE Systems Conference (SYSTEMS2003)*, 23–26 March 2009, Vancouver, BC, pp. 48–53, doi 10.1109/SYSTEMS.2009.4815770.

[50] Feng, L., Shuguang, L., Lei, Z., Lou, L., and Cheng, X., Dynamic Virtual Prototype of Soldier System, in Proceedings of *IEEE Conference on Control 2008*, July 16–18, Kunming, China, pages: 329–333, doi 10.1109/CHICC.2008.4605604.

[51] Field Manual FM 1-02, www.armypubs.army.mil/doctrine/Active_FM.html accessed on 8.8.2012], FM 1-02, 21.9.2004, accessed on 8.8.2012.

[52] Field Manual 21-18, www.25idl.army.mil/PT/fm21_18.pdf] FM 21-18, accessed on 8.8.2012.

[53] Fong, L.L,. Kalantar, M., Pazel, D.P., Goldszmidt, G.S., Fakhouri, S., and Krishnakumar, S., Dynamic resource management in an eUtility, in Proceedings of IEEE Conference on Network Operations and Management Symposium (NOMS2002), Florence, Italy, pp. 727–740, doi 10.1109/NOMS.2002.1015620.

[54] Fragouli, C., Katabi, D., Markopoulou, A., Rahul, M., and Hariharan, R., Wireless Network Coding: Opportunities & Challenges, in Proceedings of *IEEE International Conference on Military Communications (MILCOM2007)*, 29–31 Oct. 2007, Orlando, FL, USA., pp. 1–8, doi 10.1109/MILCOM.2007.4454988.

[55] Frankot, R.T., Performance of cued target acquisition systems: Impact of automatic target recognition, in Proceedings of *42nd Conference on Asilomar Signals, Systems and Computers (ACSSC2008)*, pp. 1619–1623, doi 10.1109/ACSSC.2008.5074697.

[56] Freespaceoptics, http://www.freespaceoptics.org/freespaceoptics/default.cfm, retrieved 2. April 2010.

[57] Ganguly, A., Agrawal, A., Boykin, P.O., and Figueiredo, R., WOW: Self-Organizing Wide Area Overlay Networks of Virtual Workstations, in Proceedings of *15th IEEE Conference on High Performance Distributed Computing, 2006*, Paris, France, pp. 30–42, doi 10.1109/HPDC.2006.1652133.

[58] Ghazal, T., Morley, R., Terry, E., and Klingaman, R., Soldier tactical mission system combat effectiveness, in Proceedings of *Systems and Information Engineering Design Symposium*, 24–25 April 2003, pp. 153–156, doi 10.1109/SIEDS.2003.158018.

[59] Ghosh, A., Verma, P., Cheng, S., and Venugopalan, A., A Free Space Optics Based Identification and Interrogation System, in Proceedings of *IEEE Conference on Homeland Security 2007*, pp. 25–27, doi, 10.1109/THS.2007.370014.

[60] Gravel, A. Fu, X. and Su, J. An Analysis Tool for Execution of BPEL Services, in Proceedings of *the 9th IEEE International Conference on E-Commerce Technology and the 4th IEEE International Conference on Enterprise Computing, E-Commerce, and E-Services (CEC-EEE2007)*, Tokyo, pp. 429–432, doi 10.1109/CECEEE. 2007.19.

[61] Hagen, P.E., Midtgaard, O., and Hasvold, O., Making AUVs Truly Autonomous, in Proceedings of *OCEANS 2007*, Sept. 29 2007–Oct. 4 2007, Vancouver, BC, pp. 1–4, doi 10.1109/OCEANS.2007.4449405.

[62] Hague, D., Kung, H.T., and Suter, B., Field Experimentation of Cots-Based UAV Networking, in Proceedings of *IEEE Conference on Military Communications (MILCOM2006)*, 23–25 Oct. 2006, pp. 1–7, doi 10.1109/MILCOM.2006.302070.

[63] Hallberg, N., Andersson, R., and Ölvander, C., Agile Architecture Framework for Model Driven Development of C^2-Systems, *The Journal of The International Council on Systems Engineering, vol 13, No 2, Summer 2010*, pp. 175–185, ISSN 1098-1241.

[64] Hanratty, T. Yen, J. McNeese, M. Sooyoung Oh Hyun-Woo Kim Minotra, D. Strater, L., and Cuevas, H., Knowledge visualization to enhance human-agent situation awareness within a computational Recognition-Primed Decision system, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM2009)*, Boston, MA, 18–21 Oct. 2009, pp. 1–7, doi 10.1109/MILCOM.2009.5379847.

[65] Harrald, J, and Jefferson, T., Shared Situational Awareness in Emergency Management Mitigation and Response, in Proceedings of *40th Annual Hawaii International Conference on System Sciences (HICSS 2007)*, Jan. 2007, Waikoloa, HI, pp. 23–23, doi 10.1109/HICSS.2007.481.

[66] Hayden, T.W., and Ward, C., Human collaboration tools for net-centric operations, in *Proceedings of the 2005 International Symposium on Collaborative Technologies and Systems*, 20–20 May 2005, St Louis, MO, pp. 20, doi 10.1109/ISCST.2005.1553286.

[67] He, J. Yen, I-L. Peng, T. Dong, J. and Bastani, F., An Adaptive User Interface Generation Framework for Web Services, in Proceedings of *IEEE Conference on Congress on Services Part II, 2008. SERVICES-2*, Beijing, 23–26 Sept. 2008, pp. 175–182, doi 10.1109/SERVICES-2.2008.23.

[68] Heissler, J., Kaplan, D., Manoski, S., and Wu, J., Collaborative Planning Over Low Bandwidth Tactical Networks, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM 2004)*, vol 2, pp. 630–634, doi 10.1109/MILCOM.2004.1494862.

[69] Herold, D., L. Griffiths, and T.Y. Fung, Lightweight, High-Bandwidth Conformal Antenna System for Ballistic Helmets, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2007)*, Orlando, FL, U.S.A., pp. 1–6, doi 10.1109/MILCOM.2007.4455055.

[70] Hojaji, F., Reza, M., and Shirazi, A., Developing a More Comprehensive and Expressive SOA Governance Framework, in Proceedings of *the 2nd IEEE International Conference on Information Management and Engineering (ICIME)*, 16–18 April 2010, Chengdu, pp. 563–567, doi 10.1109/ICIME.2010.5478046.

[71] Hue, M., Substantiating the Value Proposition for NCW – Metrics and Indicators, *Journal of Battlefield Technology, Vol 12, No 1*, March 2009, pp. 1–7.

[72] Jacoby, G.A., and Chang, D.J., Towards command and control networking of cooperative autonomous robotics for military applications (CARMA), in Proceedings of *Electrical and Computer Engineering (CCECE 2008)*, pp. 000815–000820, doi 10.1109/CCECE.2008.4564649.

[73] Jakobson, G, Buford, J., and Lewis, L., A Framework of cognitive situation modelling and recognition, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2006)*, 23–25 Oct. 2006, Washington, DC. pp. 1–7, doi 10.1109/MILCOM.2006.302076.

[74] Jiang, M., and Willey, A., Service-Oriented Architecture for Deploying and Integrating Enterprise Applications, in Proceedings of *5th Working Conference on Software Architecture (WICSA 2005)*, Pittsburg, PA, pp. 272–273, doi 10.1109/WICSA.2005.60.

[75] Jormakka, J., A Cyptoprotocol for Exchanging One time Pads, in *User's view on battlespace systems*, National Defence University, Department of Military Technology, Series 3, no 9, ISBN 978-951-25-1993-4, Edita, Helsinki 2009, pp. 137–147.

[76] Jormakka, J., and Lucenius, J., Possibilities for improving dependability of C^4I^2SR systems based on Service Oriented Architecture, in *IEEE Transctions 2009 Computation World: Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns*, pp. 315–324, doi 10.1109/ComputationWorld.2009.74., ISBN: 978-1-4244-5166-1.

[77] Joze, M., Fras, M., and Cucej, Z., New approach to the modeling of Command and Control Information Systems, in Proceedings of *IEEE Conference on Military Communications (MILCOM2008)*, 16–19 Nov. 2008, San Diego, CA, pp. 1–7, doi 10.1109/MILCOM.2008.4753134.

[78] Juarez, J., Dwivedi, A., Hammons. A., Jones, S., Weerackody, V., and Nichols, R., Free-Space Optical Communications for Next-Generation Military Networks, in *IEEE Communications Magazine, November 2006*, pp. 46–51, doi 10.1109/MCOM.2006.248164.

[79] Jun, Y., Yuan, H-z., Zhang, Xq., and Gao, Z-s., Face Recognition Based on Wavelet Transform and Image Principle Component Analysis, in Proceedings of *IEEE International Conference Computer and Electrical Engineering (ICCEE2008)*, 20–22 Dec. 2008, Phuket, pp. 354–357, doi 10.1109/ICCEE.2008.34.

[80] Järvinen, R., Määttä, J., Luostarinen, R., Manner, J., and Luoma, M., MICS Messaging Platform: Architecture, Design and Routing, in Proceedings of *IEEE International Conference on Military Communications (MILCOM2010)*, pp. 1893–1898, doi 10.1109/MILCOM.2010.5680396.

[81] Kaufman, A., Critical Factors Affecting the Military Utility of Networking, *Journal of Battlefiled Technology, November 2005, Vol 8 Number 3*, ISSN 1440-5223, pp. 27–32.

[82] Kazaura, K., Wakamori, K., Matsumoto, M., Higashino, N., Tsukamoto, K., and S. Komaki, A Proposal for a Broadband Wireless Access Technology based on Radioon FSO Links, in Proceedings of *IEEE GLOBECOM Workshops*, Nov. 30–Dec 4, 2008, New Orleans, U.S.A., pp. 1–6, doi 10.1109/GLOCOMW.2008.ECP.71.

[83] Khan, S., and Tokarchuk, L. N., Interest-Based Self Organization in Group-Structured P2P Networks, in Proceedings of *IEEE 6th Conference on Consumer Communications and Networking (CCNC 2009)*, 10–13 Jan. 2009, Las Vegas, NV, pp. 1–5, doi 10.1109/CCNC.2009.4784959.

[84] Kikiras, P., An Integrated Platform for Autonomic Computing for Disaster Relief Operations, *Journal of Battlefield Technology, Vol 12 Number 3*, ISSN 1440-5113, November 2009, pp. 29–34.

[85] Kopp, C., Fifteen Constraints to the Capability of High Capacity Mobile Military Networked Systems, *Journal of Battlefield Technology, Vol 10 Number 2*, ISSN 1440-5113, July 2007, pp. 15–20.

[86] Lampton, R., Cohn, J., Endsley, M., Freeman, J., Gately, M., and Martin, G., Measuring Situation Awareness for Dismounted Infantry Squads, in Proceedings of *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC)*, 2005.

[87] Lan, J., and Shen, Z., New approach of imagery generation and target recognition based on 3D LIDAR data, in Proceedings of *IEEE Conference on Electronic Measurement & Instruments (ICEMI2009)*, pp. 1–612–1–616, doi 10.1109/ICEMI.2009.5274790.

[88] Leibowitz, B., Boser, B., and Pister, K., A 256-element CMOS Imaging Receiver for Free-Space Optical Communication, *Journal of Solid-State Circuits, vol 40, issue 9*, 1948–1956, doi 10.1109/JSSC.2005.848148.

[89] Leung, K.F., Leung, F.H.F., Lam, H.K., Tam, P.K.S., Recognition of speech commands using a modified neural fuzzy network and an improved GA, in Proceedings of *the 12th IEEE International Conference on Fuzzy Systems (FUZZ '03)*, 25–28 May 2003, vol.1, pp. 190–195, doi 10.1109/FUZZ.2003.1209360.

[90] Lewis, G. Morris, E. Smith, D, The Service-Oriented Migration and Reuse Technique (SMART), Technical report CMU/SEI-2005-TN, Software Engineering Institute, in Proceedings of *13th International Workshop on Software Technology and Engineering Practice*, September 2005, Budapest, pp. 222–229, doi 10.1109/STEP.2005.24.

[91] Li, J., and AlRegib, G., Optimal Weighted Data Gathering in Multi-Hop Heterogeneous Sensor Networks, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2008)*, San Diego, CA, USA, pp. 1–7, doi 10.1109/MILCOM.2008.4753346.

[92] Libiao, T. ; Lu, W., Qi, D., Kai, Z., Target Recognition Based on Seismic Sensors and Neural Network, in Proceedings of *8th International Conference on Electronic Measurement and Instruments (ICEMI '07)*, Aug. 16 2007–July 18 2007, Xi'an, pp. 1-18–1-21, doi 10.1109/ICEMI.2007.4350418.

[93] Lightpointe, Free Space Optics, http://www.freespaceoptics.org/freespaceoptics/default.cfm, retrieved on 04.04.2010.

[94] Liu, L., Russell, D., Looker, N., Webster, D., and Xu, J., Delivering Sustainable Evolutionary Service-Oriented Architecture for Network Enabled Capability, in Proceedings of *International Workshop on Verification and Evaluation of Computer and Communication Systems (VECoS2008)*, pp. 1–11.

[95] Liu, X., Zhiyi Fang, Z., and Shi, L., Securing Vehicular Ad Hoc Networks, in Proceedings of *2nd International Conference on Pervasive Computing and Applications, (ICPCA 2007)*, 26–27 July 2007, Birmingham, pp. 424–429, pp doi 10.1109/ICPCA.2007.4365481.

[96] Loren E., Riblett, L., and Wiseman, J., TACKNET: Mobile Ad Hoc Secure Communications Network, in Proceedings of *41st Annual IEEE International Carnahal Conference on Security Technology*, 8–11 October 2007, Ottawa, Ontario, Canada, pp. 156–162.

[97] Lund, K., Eggen, A., Hadzic, D., Hafsoe, T., and Johnsen, F.T., Using web services to realize service oriented architecture in military communication networks, *Communications Magazine, vol 45, Issue 10*, pp. 47–53, doi 10.1109/MCOM.2007.4342822.

[98] Luo, B; Zhang, Y., and Pan, Y-H., Face recognition based on wavelet transform and SVM, Conference on Information Acquisition, in Proceedings of *IEEE International Conference on Information Acquisition*, 27 June–3 July 2005, doi pp. 373–377, doi 10.1109/ICIA.2005.1635115.

[99] Luo, R. C., Chou, Y., Chung T., Liao, C., Lail, C., and Tsai, C., NCCU Security Warrior: An Intelligent Security Robot System, in Proceedings of *33rd IEEE Conference on Industrial Electronics Society (IECON 2007)*, 5–8 Nov. 2007, Taipei, pp. 2960–2965, doi 10.1109/IECON.2007.4460380.

[100] Luo, R.C., Zhan, J.W., Cheng, W.H., and Chang, N.W., Network-based multimodal Human-Robot Interactions in ubiquitous computing environment, in Proceedings of *IEEE International Conference on Robotics and Biometrics (ROBIO2009)*, Bangkok, 22–25 Feb. 2009, pp. 131–136, doi 10.1109/ROBIO.2009.4912992.

[101] Mahdy, A.M., and Deogun, J.S., Optimizing Free Space Optics for City-Wide Wireless Networks, in Proceedings of the *Sixth International Conference on Networking (ICN '07)*, Martinique, pp. 66, doi10.1109.2007.66.

[102] Marth, R.B., Sr., Levi, R., Durboraw, I.N., and Beam, K., The integrated navigation capability for the Force XXI Land Warrior, Position Location and Navigation Symposium, in Proceedings of *IEEE Conference on Position Location and Navigation Symposium*, Palm Springs, CA, 20–23 Apr 1998, pp. 193–200, doi 10.1109/PLANS.1998.670041.

[103] Martini, A; Mourão, S; Silva, W., What Now: A System to Enable Videostream in a Mobile Network, in Proceedings of *IEEE Conference on Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns, Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns, 2009 (COMPUTATIONWORLD '09)*, Athens, Greece, pp. 557–562, doi 10.1109/ComputationWorld.2009.99.

[104] Matsuoka, M., Rock, S. M and Bualat, M. G., Autonomous Deployment of a Self-Calibrating Pseudolite Array for Mars Rover Navigation, in Proceedings of *Position Location and Navigation Symposium, PLANS 2004*, 26–29 April 2004, pp. 733–739, doi 10.1109/PLANS.2004.1309067.

[105] Maule, R.W., Enterprise knowledge security architecture for military experimentation, in Proceedings of *IEEE International Conference on Systems, Man and Cybernetics, 2005, vol 4*, pp. 3409–3414, doi 10.1109/ICSMC.2005.1571674.

[106] Maule, R.W., Schacher, G., Gallup, S.P., and McClain, B., Applied knowledge analytics for military experimentation, Proceedings of *IEEE International Conference on Information Reuse and Integration, 2004, (IRI 2004)*, pp. 91–96, doi 10.1109/IRI.2004.1431442.

[107] Maybury, M., Collaboration Operations: Ensuring Success, Proceedings of the 2005 in Proceedings of *International Symposium on Collaborative Technologies and Systems*, 20–20 May 2005, St. Louis, MO, pp. 2–3, doi 10.1109/ISCST.2005.1553273.

[108] Medlow, M., Extending Service-Oriented Architectures to the Deployed Land Environment, *Journal of Battlefield Technology, vol. 13, No. 1*, March, 2010, pp. 27–33.

[109] Miles L.D., Techniques of Value Analysis and Engineering, 2nd. edition, McGraw-Hill, New York,1972.

[110] Minami, N. and Rhodes, D. Dynamic Analysis of the Brigade Combat Team's C^2 Architecture, *Journal of Battlefield Technology, Vol 11, No 2*, July 2008, pp. 9–14.

[111] Misra, P., Burke, B., and Pratt, M., GPS Performance in Navigation, Proceedings of IEEE, Jan 1999, vol 87, issue 1, Jan 1999, vol 87, issue 1, pp. 65–68, doi 10.1109/5.736342.

[112] Murray, J, Wearable computers in battle: recent advances in the Land Warrior system, in Proceedings of *the Fourth International Symposium on Wearable Computers (ISWC)*, Atlanta, Georgia, 16–17 October, 2000 pp. 169–170, doi 10.1109/ISWC.2000.888485.

[113] Nordman, M., Quality of Service in Tactical Ad Hoc Networks, Licentiate thesis, Tampere University of Technology, 2006.

[114] Oksa, S., The average military C^4I system user: A Turing's machine or a frightened animal, *Users view on battlespace systems*, Finnish National Defence University, Department of Military Technology, Series 3 No 9, pp. 81–100.

[115] Ospital, E., and Wojack, A., A Holistic Approach to Combat Identification, *Journal of Military Technology, vol XXXIV, issue 9*, 2010, ISSN-3226, pp. 68–73.
[116] Pachter, M., Ceccarelli, N., and Chandler, P.R., Vision-based target geo-location using camera equipped MAVs, in Proceedings of *46th Conference on Decision and Contro (CDC2007), 2007*, pp. 2333–2338, doi 10.1109/CDC.2007.4434038.
[117] Panahi, M., Nie, W., Lin, and K-J., The Design and Implementation of Service Reservations in Real-Time SOA, in Proceedings of *IEEE International Conference on e-Business Engineering (ICEBE2009)*, 21–23 Oct. 2009, Macau, pp. 129–136, doi 10.1109/ICEBE.2009.26.
[118] Park, K., Nishiyama, H., Ansari, N., and Kato, N., Certificate Revocation to Cope with False Accusation in Mobile Ad Hoc Networks, in Proceedings of *2011 IEEE International Conference on Communications, Source of Innovation: Back to the Origin*, 5–9 June, 2011 Kyoto, Japan, pp. 1–5.
[119] Phister, P., Knowledge Centric Operations: Implications to Future Command and Control, in Proceedings of *Aerospace Conference (AERO2005)*, 5–12 March 2005, Big Sky, MT, pp. 4017–4026, doi 10.1109/AERO.2005.1559707.
[120] Preden, J., and Pahtma, R., Exchanging situational information in embedded networks, in Proceedings of *2nd International Conference on Adaptive Science & Technology, 2009. ICAST 2009*, pp. 265–272, doi 10.1109/ICASTECH.2009.5409713.
[121] Qu, Y., Wang, T. and Zhu, Z., Remote audio/video uman signature detection, in Proceedings of *IEEE Conference on Computer Vision and Pattern Recognition Workshops, CVPR, 2009*, pp. 66–71, doi 10.1109/CVPRW.2009.5204294.
[122] Qu, Y., Zhang, Y., and Zhou, Q., Cooperative Localization of UAV Based on Information Synchronization, in Proceedings of the *2010 IEEE International Conference on Mechatronics and Automation*, August 4–7, 2010, Xi'an, China, pp. 225–230, doi 10.1109/ICMA.2010.5589081.
[123] Raghavan, R.S., Kam, A., and Mannepalli, R.Y., Modeling & simulation to study the performance of hybrid free space optical/rf military communication networks, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM 2008)*, 16–19 Nov. 2008, San Diego, CA, pp.1–7, doi 10.1109/MILCOM.2008.4753149.
[124] Rahimi, S., Mohamed, H., Paredes, N., Company Command Support System CS^2, in Proceedings of *IEEE Symposium on Systems and Information Engineering Design, 2007 (SIEDS 2007)*, pp. 1–4, doi 10.1109/SIEDS.2007.4374016.
[125] Raygan, R.E., and Green, D.G., Internet collaboration: TWiki, Proceedings of *IEEE Conference Southeast 2002*, Columbia, SC, USA, pp. 137–144, doi 10.1109/.2002.995573.

[126] Rein, K., Schade, U., and Hieb, M., Battle Management language (BML) as an enabler, in Proceedings of *IEEE International Conference on Communications (ICC'09)*, 14–18 June, Wachtberg, Germany, 2009, pp. 1–5, doi 10.1109/ICC.2009.5198779.

[127] Ruan, Z., Ngai, E.C.-H., and Liu, J., Wireless sensor network deployment in mobile phones assisted environment, in Proceedings of *18th International Workshop on Quality of Service (IWQoS)*, 16–18 June 2010, Beijing, pp. 1–9, doi 10.1109/IWQoS.2010.5542754.

[128] Ruangwiset, A., Path Generation for Ground Target tracking of Airplane-typed UAV Proceedings of *the 2008 IEEE International Conference on Robotics and Biomimetics* (ROBIO), Bangkok, Thailand, February 21–26, 2009, pp. 1354 – 1358, doi 10.1109/robio.2009.4913197.

[129] Rubin, I., Behzad, A., Runhe, Z., Huiyu, L., and Caballero, E., TBONE: A mobilebackbone protocol for ad hoc wireless networks, in Proceedings of *IEEE Conference on Aerospace (AERO2002)*, vol 6, pp. 6-2727–6-2740, doi 10.1109/AERO.2002.1036113.

[130] Russell, D., Looker, N., Lu, L., and Xu, J., Service-Oriented Integration of Systems for Military Capability, in Proceedings of *11th IEEE International Symposium on Object Oriented Real-Time Distributed Computing (ISORC)*, 2008, pp. 33–41, doi 10.1109/ISORC.2008.45.

[131] Schuck, T., An Extended Enterprise Architecture for a Network-Enabled, Effects-Based Approach for National Park Protection, *Journal of Systems Engineering, vol 13, No 3, Fall 2010*, on pp. 209–216, ISSN 1098-1241.

[132] Segal, H., Pike, D., and Cleave, R.R., Reliable communication links between the military and First Responders, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM 2008)*, 16–19 Nov. 2008, San Diego, CA, pp.1–6, doi 10.1109/MILCOM.2008.4753060.

[133] Seidel, S., Krout, T. and Stotts, L., An Adaptive Broadband Mobile Ad-Hoc Radio Backbone System, in Proceedings of *1st IEEE Workshop on Networking Technologies for Software Defined Radio Networks (SDR '06)*, 25–25 Sept. 2006, Reston, VA, USA, pp. 1–7, doi 10.1109/SDR.2006.4286320.

[134] Sierksma, T.,Hoekstra, J., Jansen, B., Boltjes, B., and van den Oever, J., Geographical based Situational Awareness in Military Mobile Domain, in Proceedings of *IEEE Conference on Military Communications Conference (MILCOM2007)*, 29–31 Oct. 2007, Orlando, FL, USA, pp. 1–7, doi 10.1109/MILCOM.2007.4455345.

[135] Soini, J., Linna, P., Leppäniemi, J., and Jaakkola, H., Towards Collaborative Situational Awareness in a time-critical Operational Environment, in Proceedings of *International Conference on Management of Engineering & Technology (PICMET 2009)*, 2–6 Aug. 2009, Portland, OR, pp. 266–270, doi 10.1109/PICMET.2009.5262236.

[136] Sonnenberg, J., Kota, S., and Jones, A., A Framework for Net-Centric Services and Usage Patterns in Military Networks, in Proceedings of *IEEE Conference on Military Communications (MILCOM2009)*, 18–21 October, 2009, Boston, MA, pp. 1–6. doi 10.1109/MILCOM2009.5379767.

[137] Spiesshoefer, S.A., Nanotechnology and its impact on communications for the warfighter, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2008)*, San Diego, CA, 16–19 Nov. 2008, pp. 1–4, doi 10.1109/MILCOM.2008.4753096.

[138] Suh N.P., Axiomatic Design of Mechanical Systems, *ASME 50th Anniversary Design Issue:Journal of Mechanical Design and Journal of Vibration and Acoustics*, Vol. 117, pp. 2–10, June 1995.

[139] Suh, N.P., The Principles of Design, Oxford University Press, New York, 1990. ISBN 0-19-504345-6.

[140] Sulistyawati, K., and Yoon P. C., System Evaluation from Team Situation Awareness Perspective, in Proceedings of *IEEE International Conference on Systems, Man and Cybernetics (SMC '06)* pp. 2831–2836, doi 10.1109/ICSMC.2006.385303.

[141] Takahashi, Y., Sugiyama, K., Ohsaki, H., Imase, M., and Murayama, J., Group-Oriented Communication: Concept and Network Architecture, Computer Communications and Networks, in Proceedings of *IEEE Proceedings of 17th International Conference on Computer and Networks* 2008. ICCCN '08, 3–7 Aug. 2008, St. Thomas, U.S.V.I., USA, pp. 1–7, doi 10.1109/ICCCN.2008.ECP.179.

[142] Tate, M., and Nordlund M., A Design Process Roadmap as a General Tool for Structuring and Supporting Design Activities, Proceedings of the Second World Conference on Integrated Design and Process Technology (IDPT-Vol. 3), Society for Design and Process Science, Austin, TX, pp. 97–104, Dec. 1–4, 1996.

[143] Torrieri, D., and Bakhru, K., Indoor Geolocation for Military Applications, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2007)*, 29–31 Oct. 2007, Orlando, FL, pp. 1–6, doi 10.1109/MILCOM.2007.4455334.

[144] Tsai W. T., Huang, Q., Xu, J., Chen, Y., and Paul, R., Ontology-based Dynamic Process Collaboration in Service-Oriented Architecture, in Proceedings of *IEEE International Conference on Service-Oriented Computing and Applications (SOCA '07)*, 19–20 June 2007, Newport Beach, CA, pp. 39–46, doi 10.1109/SOCA.2007.35.

[145] Ulicny, B. Matheus, C., Kokar, M., and Powell, G., Problems and Prospects for Formally Representing and Reasoning about Enemy Courses of Action, in Proceedings of *IEEE 11th International Conference on Information Fusion, 2008*, Cologne, Germany, pp. 1–8, ISBN: 978-3-8007-3092-6.

[146] Villavicencio, O., Lu, K., Zhu, H., and Kota, S., Performance of IEEE 802.11n in Multi-Channel Multi-Radio Wireless Ad Hoc Network, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2007)*, 29–31 Oct. 2007, Orlando, FL, USA, pp. 1–6, doi 10.1109/MILCOM.2007.4454755.

[147] Wang, F., Tang, H., Yu, F.R., and Mason, P.C., A hierarchical identity based key management scheme in tactical Mobile Ad Hoc Networks, in Proceedings of *IEEE Conference on Military Communications, 2009, (MILCOM 2009)*, 18–21 Oct. 2009, Boston, MA, pp.1–7, doi 10.1109/MILCOM.2009.5379731.

[148] Wang, X., and Qi, H., Collaborative unknown target recognition in sensor networks, in Proceedings of *19th National Conference on Artificial Intelligence (AAAI), Workshop on Sensor Networks*, San Jose, CA, July 26, 2004.

[149] Wei, W., Zongyu, L., and Rongrong, X., INS/GPS/Pseudolite integrated navigation for land vehicle in urban canyon environments, in Proceedings of *IEEE Conference on Cybernetics and Intelligent Systems*, Singapore, vol 2, pp. 1183–1186, doi 10.1109/ICCIS.2004.1460758.

[150] White, T., Transforming the US Army, Military Technology 10/2010, pp. 10–22, ISSN 0722-3226.

[151] Williams, L., Small Unit Operations Situation Awareness System (SUO SAS): An Overview, in Proceedings of *IEEE Conference on Military Communications (MILCOM 2003)*, Vol 1, pp. 174–178, doi 10.1109/MILCOM.2003.1290098.

[152] Xu, W-h., Zhang Y., and Li, Z-x., Lightweight weapon system for robot soldier, in Proceedings of *4th IEEE Conference on Industrial Electronics and Applications, 2009, (ICIEA 2009)*, pp. 1727–1729, doi 10.1109/ICIEA.2009.5138492.

[153] Younis, O., Kant, L., Mcauley, A., Manousakis, K., Shallcross, D., Sinkar, K., Chang, K., Young, K., Graff, C., and Patel, M., Cognitive tactical network models, *IEEE Communications Magazine, October 2010, vol 48, Issue: 10*, pp. 70–77, doi 10.1109/MCOM.2010.5594679.

[154] Younis, O., Kant, L., Chang, K., Young, K., and Graff, C., Automating design of MANETs for future force networks, in Proceedings of *IEEE Conference on Military Communications (MILCOM2009)*, 18–21 Oct. 2009, Boston, MA, pp. 1–7, doi 10.1109/MILCOM.2009.5380069.

[155] Zari, M.C., Zwilling, A.F., Fikes, J.W., Hess, D.A., Ward, R.N., Anderson, C.S., and Chiang, D.J., Personnel identification system utilizing low probability-of-intercept techniques: prototype development and testing, in Proceedings on *The Institute of Electrical and Electronics Engineers 31st Annual 1997 International Carnahan Conference on Security Technology*, 15–17 Oct 1997, Canberra, ACT, pp. 224–230, doi 10.1109/CCST.1997.626274.

[156] Zeeb, E., Bobek, A., Bohn, H., and Golatowski, F., Service-Oriented Architectures for Embedded Systems Using Devices Profile for Web Services, in Proceedings of *IEEE 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW '07)*, 21–23 May 2007, Niagara Falls, Ont., pp. 956–963, doi 10.1109/AINAW.2007.330.

[157] Zheng, H., Shi, L, Cao, L., Group-Mobility-Aware Spectrum Management for Future Digital Battlefields, in Proceedings of *IEEE Conference on Military Communications (MILCOM2006)*, 23–25 Oct. 2006, Washington, DC, pp. 1–7, doi 10.1109/MILCOM.2006.3020

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