The Integrated Digital Soldier System

Close Combat in the 21st Century

Abstract

This paper examines tactical warfighting in a near peer or peer threat environment in the 21st Century. The prevalence of sophisticated ubiquitous sensors across multiple spectrums drives a requirement for exceptional situational awareness and signature management at the tactical level. Research shows that situational awareness, as knowledge, is best presented to the warfighter as part of an augmented reality in a heads-up display, using three dimensional natural shapes and colours. This assimilation can be more rapidly undertaken and supported with the use of visualised uncertainty to support the combatant situational awareness. Situational awareness is the key driver to success in modern warfighting. Continued adherence to norms in warfighting will not prepare the Australian Army for the next war.

Introduction

Digitisation is more than people and systems being able to connect effectively with each other. Digitisation is the evolution of communication from voice and text for transmission of information (information sharing) on a broad scale across the entire force as close to simultaneously as possible. In realizing digitisation in that context, the ability to use that information in a useful and timely fashion is paramount.

Digitisation's purpose is to support the combatant. The ground combatant and, in particular, the close combatant, has five key combat needs. These are:

- Situational awareness (SA) or cognition
- Agility (mobility)
- Lethality
- Protection (survivability)
- Sustainability (logistics)

Each of these is important. It can be argued that, of all these needs, SA is the key overriding issue. In combat, irrespective of any other attribute of the combatant, SA is the most important attribute keeping the combatant alive and effective. (1) When the combatant has superior SA to an adversary, this allows the combatant to dictate the terms on which the battle is fought, whether at the tactical, operational or strategic level. (2) SA is afforded by knowledge, which must be assimilated. (3) The combatant who assimilates the essential knowledge fastest achieves superior SA. (1)

Next is agility, which includes mobility. Agility can be a positive support to SA, allowing the combatant to position, but not necessarily manoeuvre, to attain superior SA, as well as to improve lethality, protection and sustainability. (4) Agility, or more specifically the lack of it, can also be highly detrimental to SA. Overburdening the combatant significantly degrades the combatant's cognitive ability, which then degrades assimilation and thus SA. The greater the burden, the faster and more pronounced the cognitive decline. (5) (6)

Lethality is important but direct engagement in combat will prevent the combatant from functioning in what should be their primary role in modern combat, of sensor (and node). (7) Exponentially greater, and more accurate, firepower (lethality) can be obtained from external sources. From the air there are (or soon will be) loitering munitions and close air support (CAS) in the form air to surface missiles. (8) (9). From land, fires including artillery, mortars and a future new long-range rocket system capable of providing fire support from ranges of up to 300km. (10) Small arms, much like ballistic protection, should be a last resort, much like the use of ballistic plates are the last barrier in protection. (7)

Protection is primarily afforded by SA. (11) In 21st Century combat, (7) (12) if the combatant is aware of the threat before the adversary, the combatant can take protective measures, whether offensive or defensive. (1) Ballistic protection is one aspect but in the modern warfare context (13) but signature management (SM) is the primary driving factor. (14) (15) If SM fails (16) (17) (18) or, is discarded, survivability (protection) in close combat is primarily afforded by SA, agility and lethality. (7) Too much emphasis on protection (risk management) is highly detrimental to SA and agility, the primary keys to success in combat. (6)

Sustainability underpins the four active aspects of the combatant's needs. The close combatant must be sustained just enough to maintain peak performance, but not too much, as this will be detrimental to the performance requirement. (11) (19) (20) SA and agility, in particular, should always outweigh a 'just in case' mentality. (4)

In view of these statements, with SA as the key driver to success in modern combatant, assimilation of knowledge is the key driver to SA. As will be outlined in this paper, assimilation of knowledge on the battlefield can be accomplished faster and more comprehensively with visualisation of knowledge. (21) (3) For visualisation of knowledge to be most effective, it is best presented as 3D volumetric natural shapes, preferably as augmented reality (AR). These 3D volumetric shapes can be supported by colours (22) (23) and supported by representation of uncertainty in that knowledge to support decision making. (24)

The Modern Soldier

Australian soldiers in the first two decades of the 21st Century are still fighting much as they did at the end of the 20th Century. The equipment has improved substantially in quality, (25) (26) (27) and technology (28) is more widely distributed, but it's integration into the whole is nonetheless still poor. (29)

Modern soldiers wear a ballistic helmet, ballistic eyewear, and ballistic body armour; hearing protection, load carriage, uniform and boots. They carry an automatic weapon with a night vision device (NVD), in addition to a binocular night vision device (BNVD) worn on the head. They are sometimes carried in a helicopter, armoured vehicle or an unarmoured vehicle as a disengaged passenger. They communicate verbally using a radio with power supplied from disposable batteries in the devices that require these. Anything a soldier sees can only be distributed to team members via voice. Their camouflage consists of face paint, a disruptive pattern with Near Infrared (NIR) attributes on their clothing and equipment, or a camouflage net that is also of a disruptive pattern. Their health in the field is determined and reported either by the individual or observations by their direct superior. Their physical work rate is guided by tables predetermined at the lowest common denominator. Whilst the Platoon they are a team member of now uses a small Unmanned Aerial System (UAS, or more commonly a drone) in the field, only the operator can see the vision and control the device. Some Commanders use a ruggedized tablet that show tactical dispositions in two dimensions (2D). Soldiers and commanders assume air superiority and an effective logistics chain supplying water, rations, ammunition and power resupply.

These same soldiers return to barracks where they don athletic garments that are specifically designed for high performance activity, quick drying and anti-microbial. They use a smart phone that enables them to video chat with multiple persons all around the globe, whilst sharing images and videos. This same mobile device enables encryption, instant deletion of text and images, and constant updates on the location of their friends and acquaintances. They can book transport, order goods and services, check the weather and access files on demand. The phone authenticates identity in multiple ways including passwords, voice and biometric data. This device can synchronize all contents automatically with other digital devices and updates automatically with the latest software including malware and virus protection.

These devices use multiple means of transmission including Bluetooth, Wi-Fi, varying generations of wireless technology and some use satellite transmission. It can be charged from the car, wall plugs, solar panel, external battery or from an inductive pad. This device seamlessly interfaces with ancillaries including microphones, headphones, styli, external speakers, displays and personal physiological data monitoring (PDM) devices. This device can synchronize with wrist worn watches that provide visual, audio and tactile extensions. In the car this device synchronizes with the vehicle's computer system for music, telephone calls and navigation, as well as locking/unlocking the vehicle. They can reconfigure lights and appliances in the home remotely, view security cameras and water the lawn. The device can fly a drone, recording and simultaneously sharing the vision with friends. They can watch a live stream from a friend's camera as they surf, ski, skateboard or even sky dive.

When relaxing the soldier plays video games using sophisticated gaming engines that seek to replicate the modern battlefield. The gaming engine allows the use a range of modern firearms and weapons. Multi participant gaming is the norm, (30) (31) with the soldier/player able to interact with other players verbally, visually and via text, as illustrated in *Figure 1* below. They can share a common point of view (POV) or as a window in window (WIW). The heads-up display (HUD) shows the personal health and usage management system (P-HUMS) of the soldier player. This includes the status of his health, ammunition/munitions, and available power on person.

The HUD can be configured by the individual from a menu, so that he only sees what is relevant to his particular needs at that time. Other information displayed can include navigations aids (e.g. directions, way points, resupply points), friendly/enemy (depicted as blue/red) element locations, communications links etc. At the same time that the player is 'playing' they may also be communicating via voice or text, or streaming the images live to other players, including WIW of their POV, or sharing their POV to someone else. Whilst the imagery is flat (2D) his mind perceives it in three dimension (3D), with depth perception automatically assimilated by his mind.

Juxtaposing these two environments, for the same person, provides a glaring gulf that has developed between developed world civilian paradigm, and that of the Australian land combatant. In comparison, the air and naval combatants exist within technological environments that are more sophisticated than their civilian counterparts. (32) (1)

Figure 1. Call of Duty Screenshot
(Courtesy of Activision Publishing Inc)

Current Context

5th Generation?

The term "5th Generation" (33) by itself does not convey the paradigm shift in both technology and operations that is implied by the words themselves. 5th Generation is often considered as aligning with the second perspective of the Revolution in Military Affairs (RMA), that is the evolution of weapons technology, information technology and weaponised information. (34) It should perhaps be more considered that a mature 5th Generation force, whether land, sea or air, will incorporate sensor proliferation across all imaginable spectra, exponential growth in data generation, data fusion analytics and integrated artificial intelligence. (35)

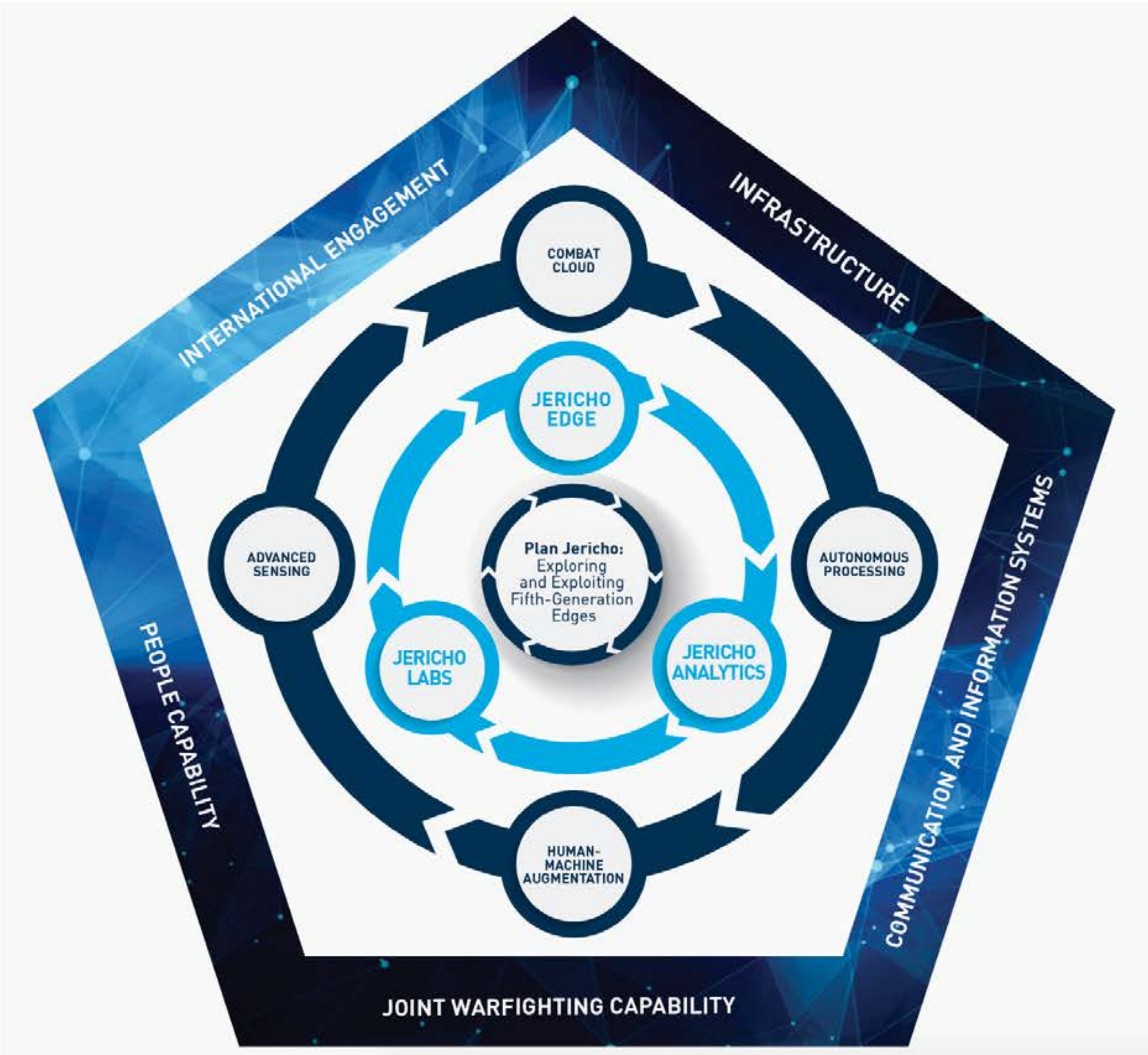

Figure 2. Plan Jericho
(Image courtesy of Commonwealth of Australia)

Plan Jericho – A 5th Generation Airforce

Under Plan Jericho, (36) with the introduction of the F-35 Joint Strike Fighter (JSF), supported by EA-18G Growler, P-8A Poseidon, E7A Wedgetail and MQ-4C Triton, Australia gains an unparalleled air capability with no regional peer. The Royal Australian Air Force (RAAF) is looking to lead with the F-35, which combines advanced stealth, integrated avionics, sensor fusion and superior logistics support with the most powerful and comprehensive integrated sensor package of any fighter aircraft in history. The F-35's advanced stealth allows pilots to penetrate areas without being detected by radars that legacy fighters cannot evade (37) (1).

The RAAF will also seek to combine human intelligence, artificial intelligence and augmented intelligence. (36) The key driver being augmented intelligence. Four focus areas will be prioritized to enable augmented intelligence. As illustrated in *Figure 2* these are:

- **The Combat Cloud.** Network integration, including machine-to machine integration, that enables the unified distribution, management, and application of resources at machine speed.
- **Advanced Sensing.** Advanced sensors to detect and track challenging targets in difficult environments and improve SA.
- **Human-Machine Augmentation.** Develop human cognitive attributes and development pathways; human-machine interfaces; and operating concepts to optimise human, machine and combined performance.
- **Autonomous Processing.** Development of artificial intelligence and machine learning that enable Defence to rapidly understand and implement broader AI developments in a transparent, explainable, and trusted manner.

Plan Pelorus/Mercator

With the advent of the latest class of Guided Missile Destroyers (DDG) and the new Hunter Class Guided Missile Frigates (FFG) for the Navy, the Royal Australian Navy (RAN) moves closer to a seamless communications meshed network, a self-healing, self-forming, and extensive IP network. (38) Inoperability within the fleet and with Coalition partners is much more advanced than either of the other services. (39) (33) That said, the RAN’s combat units comprise significantly fewer nodes to mesh than the RAAF (40) and even more significantly less than the Army. (28) In addition, each node has tremendous inherent power and systems capacity within a very tight and well drilled construct.

The Aegis Combat Systems, (41) common among Western Allies, enables the ships to operate collectively as a tight knit meshed team as well as meshing with the air assets in a highly capable environment. The RAN has realized that in the future, ships will only be entirely capable when they operate in fleet systems (39). In the future, the whole will be massively greater than the sum of its parts. (42)

The RAN also understands that there is an enormous and ever-growing collection of a variety of data that cannot be either transmitted or processed in a timely manner to be useful in battle. (39) Yet processing more information may as easily saturate commanders and their staffs with a flood of indigestible data. (42) This information overload can result when there is too much information for the commander and his staff to timely process and place into the proper context. It can also result when technical systems cannot quickly transmit relevant information to users. Among other things, one’s commanders can be overwhelmed by a vast flow of information, especially if they are not properly trained to do so. Therefore, Both the method of transmission and the method of contextualising need to be significantly improved.

Plan Beersheba

Under Plan Beersheba, (26) (43) by 2025, the Army seeks to evolve its ideas, operating concepts, structures and people so that it is best placed to exploit the opportunities of the digital age, is a capable member and contributor to the Joint force, and is able to survive and succeed in the future threat environment. (26) From 2018 to 2020 the aspirational goals include further integration of discrete networks; integration with tactical data links and wider Defence Network architectures; and cyber protection and network assurance. (36) From 2020 Army is seeking big data analysis to exploit the 'big military data' generated by the Joint Force, i.e. F-35, EA-18G, P-8A, E7A and MQ-4C. It also seeks to improve data management and continue to build cyber protection and network assurance. (26)

Army's understanding of digitisation and working within a networked Joint Force is interesting. Army has moved to embrace the clear advantages of a networked force to a degree where it is difficult to conceive a near future where most systems are not dependant on some form of digitised connectivity. (43) The concept of Network Centric Warfare (NCW) envisaged by Army in the 21st Century (44) does not appear to have evolved the force in the manner in which it thought it would. A dearth in the recognition of the value of data, and data management, from the elements of the Land Force (45), the overwhelming influx of data from Air and Naval assets, (39) (36) combined with the limitations on communications, has seen Army struggling to cope. (46)

There also appears to be some doubt within Army about the perceived value of digitisation in the medium and long term. Questions as to "*whether digitisation and networking will significantly enhance the existing force and its operating concepts or alternatively, drive the imagination of fundamental changes to existing paradigms remains to be seen*" (43) number appear to cast doubt on the requirement for, or benefits of, digitisation. (26) There appears to be an undercurrent of thought that, if the network should go down and interconnectivity is lost, will the Land Force still be able to execute or prosecute it's mission? (26)

The Army is digitising its Headquarters (HQ) elements. (43) Current roll out and employment of digital systems in Australian Army Brigades has contributed to exponential growth in the size, complexity and power requirements of those HQ, thus impacting deployability. The more digitisation, the more the concentration of specialist command elements. The more power and communications, the greater the risk of detection by adversary sensors.

Given the complexity of these newly digitised HQ elements, the greater the cost of training and maintaining the expertise. This expertise is difficult to duplicate and provide redundancy. Lack of redundancy increases the risk of system failure when that HQ is rendered non-functional (forced to move or attacked kinetically or electronically). In modern warfare, any critical command and control node becomes a singular point of failure. If the command, control and communications and intelligence (C3I) node is compromised, then all sub elements are similarly affected.

An "Army in Motion" (47) and the "Accelerated Warfare" (48) go some way to recognizing the new paradigm but, whilst recognizing the issues, don't outline a warfighting concept to address the issues.

Digitised?

For the "digitised" Army, the issues of information overload, the ability of staff to assimilate that information, combat load creep, risk management, and management versus command also come into play. This is well illustrated in an article in The British Army Review (4) which discusses in some excruciatingly accurate prose the issues of both the soldier in the field and the commander in the Headquarters. Though the context is a British one, the same issues can apply to the Australian paradigm.

The authors, 'Sons of the Iron Lady' reflect in this 2011 article that "*Last year, deployed UK headquarters produced a terabyte of written orders and reports every month. In one Afghan HQ it took a man nine days to read one day's worth of chat room and email exchanges – and he didn't have to open any of the attachments*." (4). The veracity of that statement cannot be verified and referenced, but the authors appears to be an experienced military person.

In the article the authors also discuss the issue of information, managing that information in a timely manner to fight the battle, and the number of "players" in the mix to receive and process the information.

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The transition to digitisation also results in large volumes of fused/correlated data/information which will require a significant increase in classified network bandwidth and network complexity as new sensors and platforms are acquired with increasing integration demands resulting from capabilities such as CEC (Cooperative Engagement Capability) and IFC (Integrated Fire Control). (35)

In McDonald and Blackburn's dissertation on the 5th Generation Information environment, they assert that "*Instead of concentrating a critical sensor and battle management centre on a single platform, the distribution of such capabilities across a resilient and adaptable network, consisting of multiple, smaller platforms is envisaged*." (35).

In arguing for a more dispersed management apparatus, the requirement for even more capability in internodal bandwidth comes to the fore. They argue that "If battle management is to be performed by a network of platforms, then there will need to be a communication and information network that will integrate multiple platforms and systems that were not originally designed to communicate with one another. These nodes on the network will need the processing power to correlate, fuse and even store the streams of data." (35)

Some of the characteristics of this capability that they postulate (35) include:

- A force design with functionality to maximise effect of digitised capabilities.
- Centralised Command with Distributed Control using Distributed Control and Communications Nodes.
- Redundancy and resiliency by design through duplication of select functionality across the Nodes.
- Open and standards-based architectures to support rapid upgrade / adaptation.

- Fusion where appropriate / possible.
- Integrated cyber protection.
- Sensors integrated as a part of a broader "sensor mesh".
- An ability to operate in both legacy and future Concepts of Operations (CONOPS)

These arguments address the Joint Force and aspects can certainly apply to the Land Force. The Army's current hierarchical structure, not only for command but also for data management, including storage, appears to evidence critical singular points of failure. As such, they are targets for enemy action with the aim of crippling the land force.

Accelerated Warfare (47) seeks to address a number of themes of future conflict from Army's perspective. These are:

- **Geopolitics.** The changing geopolitical order and operating spectrum of cooperation, competition and conflict.
- **The Threat.** The advent of rapidly evolving, easily accessed technology increasingly offers asymmetric capabilities to both established powers as well as non-state actors and even individuals.
- **Technology.** The convergence of big data, artificial intelligence, machine-learning, robotics, unmanned and autonomous capability with precision weaponry. Fused, synthesised and assured information for decision superiority is also likely to be an essential battlefield enabler with the challenge to protect this information from disruption and deception.
- **Domains.** Army's ability to operate in the traditional air, sea and land domains are at risk of being debilitated from space and cyber, yet these may also be the keys to dominating these domains.

Army's Accelerated Warfare concept does not address a number of 5th Generation concepts already in use, or under development with RAN and RAAF. Even the terminology seems to be different. RAN and RAAF are thinking in terms such as the 'Kill Web' (any sensor, best shooter) and the range of C2 (Command and Control), ISREW (Intelligence, Surveillance, Reconnaissance, Electronic Warfare) IFC (Integrated Fire Control) and IAMD (Integrated Air Missile Defence).

They are also considering the shift toward internet protocol (IP) data that will be essential within a multi-nodal and cross-domain environment. (35) This would include Network proliferation with special purpose applications, such as CEC (Cooperative Engagement Capability), TTNT (Tactical Targeting Network Technology) and SINGCARS (Single Channel Ground and Airborne Radio System).

McDonald and Blackburn (35) emphasise that network proliferation, for RAN and RAAF, across multiple communication bearers, nodes and protocols will continue but in a 5th Generation environment greater focus will likely be on the Common Operating Picture (COP) and the tactical subsets of the Recognised Air, Land and Maritime Pictures to enhance SA. (35)

Another major issue that McDonald and Blackburn (35) address with the technology shift is the potential to move encryption from the existing network level to the node or component. (35) This could in turn permit the use of multiple, independent, commercial, as well as military, pathways for communications and information. This distributed network modal encryption would support the idea of dispersed management apparatus of nodes and sensors.

The Combatant

Overburdening the Donkeys

Reducing the load of the soldier in the field is also crucial to winning the fight in the field. It is not simply enough to not incur casualties in a battle. The aim of the battle is to force a decision. In previous conflicts, at the basest level for the dismounted combatant, the role of infantry has been to seek out and close with the enemy, to kill or capture him, to seize and hold ground and to repel attack by day or night, regardless of season, weather or terrain. (49) Whilst there is some conjecture that the role of infantry is changing due to autonomous vehicles and stand-off weapons, does the core precept still hold true?

Soldiers struggle with the weight, bulk and utility of their combat equipment. (5) The battlefield environment is more technologically challenging than at any time in history, with remote weapons, UAVs, multi-spectral sensors and automated weapons systems.

Combatants need to be:

- equipped for battlefield contingencies (offensive & defensive), yet
- not overburdened with equipment that doesn't contribute to that mission, yet
- fresh and tactically mobile enough to fight, and
- able to integrate seamlessly into all land platforms.

It is difficult to do this when the dismounted combatant is unable to manoeuvre because of the weight of his/her equipment (see Figure 3 below). Considerable attention is currently being given to personal load carriage augmentation, such as exoskeletons. Whilst a solution may eventually come through technological advances, at the present exoskeletons add weight, require additional power and/or inhibit the manoeuvrability /comfort of the combatant when this is needed most. (50)

Figure 3. Australian Soldiers in Marching Order
Images courtesy of the Commonwealth of Australia

As with the juxtaposition of the technology use differences between the soldier in the field and the soldier in barracks, the differences in issued equipment and worn by the soldiers in the field are also of note. (5)

Whilst dated to a degree, and therefore not able to account for either new equipment issues or new restrictions on personal preference equipment in the field, the 2011 study by Defence

Science and Technology Organisation (DSTO), now the Defence Science and Technology Group (DSTG), provides an indication.

The outcomes of poor load carriage systems can be:

- **Increased injury.** Load carriage, whether excessive or cumulative, will inevitably result in musculoskeletal and soft tissue injuries. This does not just apply to dismounted combatants but also to combatants when mounted (carried in vehicles). Mounted combatants can be subject to micro vibration (not felt), macro vibration (can be felt) and movement of the vehicle in motion, all of which are amplified by the weight of the load carriage of the individual. DSTO reports have identified that "Weight load, march duration, load distribution, terrain and individual fitness levels together with load carriage equipment design contribute to the incidence of acute load carriage injuries". (51) This makes a compelling case for weight reduction in load carriage in all configurations.
- **Reduced mobility.** A DSTO research paper with the University of Wollongong in 2010 (52) demonstrated an average decrease of approximately 1.5% in soldier performance for every 1 kg increase in a load range of 19.1 to 29.2 kg across four mobility assessments. The assessment tasks included an agility course, sprinting, jumping and a simulated section attack.
- **Reduced Lethality.** Several studies have shown that accuracy in marksmanship can be significantly affected by military load carriage activities. (53) Whilst there is some discussion about the extent due to studies varying in the timeframe between the cessation of the load carriage task and the marksmanship task, those studies where the time elapse was less than 30 minutes showed detriment, increasing as the timeframe shortened.
- **Reduced cognitive ability.** During stressful combat-like training, every aspect of cognitive function is severely degraded compared with baseline, pre-stress performance. Relatively simple cognitive functions such as reaction time and vigilance are significantly impaired, as were more complex functions, including memory and logical reasoning. (6)

As this report documents, the soldier equipment burden is a long-standing problem with real consequences to both the individual soldier and their tactical performance. Whilst the causes of the excessive load carriage circumstance are numerous, and although well understood, the solution is complex A combination of weight, placement and task timeframe needs to be addressed.

Brady, Lush and Chapman's 2011 study's Soldier Equipment Survey (5) also demonstrated that soldiers were definitely experiencing problems of fatigue and injury with their load carriage equipment and were always looking for alternatives to reduce those problems. These alternatives included:

- Sourcing and carrying lighter, smaller and/or more efficient equipment than items issued.
- Failing to carry their issued equipment, after questioning its utility.
- Sourcing and using non-issued load carriage equipment.

For personal equipment, the approach taken by ultra-lightweight hikers and backpackers, as well as travellers in general, can yield useful savings. Savings may be grouped under weight or bulk, or a combination of these.

- **Weight.** New materials are available and being utilised in the civilian world (and gradually in the military world) that significantly reduce material weight. Examples include:
  - Laser cut laminates that reduce the weight of the material (laminates over nylon) but also the substance (laser cut out of extraneous non-functional material). Examples include SCE (250-500g plate carriers), load carriage (small and large packs), helmet covers, scabbards, slings, straps, stretchers etc. See

Figure 4. Laser Cut Laminates in Soldier Combat Ensembles
Images courtesy of Crye Precision

  - 3D Printing of field equipment items to remove internal volume that otherwise would be included in the weight. (54) Examples this might be include buckles, entrenching tool handles, bayonets (titanium, ceramics), UAV components (55) etc. At a higher level, replacement parts can also be manufactured on site, using recycled battlefield materials such as PET plastics, polypropylene (PP) based items such as yoghurt containers, and strengthening materials including cardboard, wood fibres and other cellulose waste materials. (56)

Figure 5. Military 3D printing in the field
Images curtesy of Popular Science

- Multi-Purpose products such as compressed rayon tablets (toilet paper, cleaning cloth, face/hand wipes, bandages, wound packing etc).
- The introduction of high intensity LED lights has had a transformative effect on reducing weight whilst increasing performance. (57)
- The transition from analogue to digital night vision show can similar, if not better, figures from manufacturers that weight savings may initially commence at 10% and then rapidly increase. The majority of this is achieved through miniaturisation of electronics compared to tubes and the use of plastics and ceramics in place of alloys. (58)

Figure 6. Digital BNVD
Images courtesy of LiveScience

- **Bulk.** New form factors and materials are available and being utilised in the civilian world (and gradually in the military world) that significantly reduce bulk while, in most cases, reducing weight. Examples include:
  - Material compression. Most modern hiking clothing is highly compressible. Modern cold weather jackets using 'hollow fibre' technology or other new synthetic materials (59) to significantly improve compressibility.

Figure 7. Compressible Cold Weather Clothing
Images courtesy of CragHoppers

  - New approaches to storage, such as roll up water bottles, (60) that may also be disposable (environmentally friendly) or recyclable (see 3D printing materials).

Figure 8. Collapsible Water Containers
Images courtesy of AnnTrue

  - Ultralight weight shelters that accommodate the individual and personal equipment, incorporate flooring, insect screen and dual layer at 680g. (61)

Figure 9. Exemplar Products – Ultralightweight Shelter
Images courtesy of REI Co-op

- Multi-environment synthetic materials. Fabric that perform differently when hot or cold (e.g. In response to sweating, the strands tighten up, activating the nanotube coating, the heat passing through the fabric, but when the body is too cold, the mechanism is reversed and closes up, trapping body heat inside). (62) Other fabrics change colour in response to commands (63) or generate power by motion or solar exposure. (64)

Figure 10. Exemplar Products (compressible, ultralightweight, adaptable)
Images courtesy of REI Co-op and Material District

A single kilogram saving provides a demonstrable mobility and cognition improvement. Every gram counts. An examination of current Tiered Body Armour System (TBAS) indicates that the system weight is around 6.5 kg for a Tier 2 baseline configuration including nylon body armour carrier, soft armour inserts and two high velocity ballistic plates). (65)

Reduction to a Laser Cut Laminate Plate Carrier would decrease this by 1000 to 1250g. Removal of the back high velocity plate (to enable comfortable seating in a vehicle) would reduce this by another 1950g. (66) Given that the risk for the prone combatant's back is fragmentation, the combined positives, of 1950g weight loss and considerable comfort for long term vehicle habitation, would seem a greater benefit than the loss of high velocity protection on the back.

What is Cognitive Ability

Cognition can be defined as a system of mental processes by which information (verbal, acoustic, tactile, visual, olfactory) is received (sensation and perception), retained (learning and memory), manipulated (thinking), and expressed (verbal, gestural, and facial communications or expressions). (67) Core cognitive functions are supported by several higher order functions, including executive function, attention, and working memory. Executive control functions sub-serve volitional, goal directed behaviours and adaptive responding to novel, ambiguous, or complex stimuli or situations (i.e. strategic planning, reasoning, inhibitory control). (68) Prior research has demonstrated that a reduction in cognitive ability can result from excessive load carriage and other stressors. (53) (51) (5).

Cognitive overload

Combatants are required to perform a wide variety of tasks in environments from training through to operational environments. Optimal execution of these military tasks requires ongoing coordination of physical and cognitive resources to meet the common and unique demands presented by both task and setting. These resources are adversely impacted by various factors such as sleep loss, physical stress, injury, environmental hazards and stressors (e.g., heat, cold, altitude, chemical threats), changes in nutritional/hydration status, and social/emotional stress. (67)

Whilst the nature of the military operations may strain physical and cognitive resources when performing mundane and repetitive job activities, there is a significantly greater impact on highly complex tasks that amplify cognitive load. The effects of degraded physical resources can be objectively evaluated within military training and operational environments using extant measures, i.e. timing of task achievement. However, the ability to assess the cognitive aspects of military performance outside of a laboratory setting are more difficult.

Military commanders, at all levels, are also required to make critical decisions and develop plans, using large and complex collections of data, in limited time frames. They may be required to do this without precise knowledge about the operating environment or the intent, capabilities or location of the adversary. Commanders need to understand the associated uncertainties so that they can understand and mitigate the operational risks involved. Therefore, it is important for decision support tools to make users aware of the uncertainties in the information being displayed in an appropriate and timely manner, while avoiding information overload. However, most visualisation techniques have been designed around the assumption that the data being visualised is free from uncertainty. (69)

Perception uncertainty

DSTG's 2016 paper (69) on this subject listed the following types of uncertainty:

- **Accuracy.** The difference between observation and reality.
- **Precision.** The quality of the estimate or measurement.

- **Completeness.** The extent to which information is comprehensive.
- **Consistency.** The extent to which information elements agree.
- **Lineage.** The pathway through which information has been passed.
- **Currency.** The time span from occurrence to information presentation.
- **Credibility.** The reliability of the information source.
- **Subjectivity.** The extent to which the observer influences the observation.
- **Interrelatedness.** The dependence on other information.
- **Experimental.** The width of a random distribution of observations.
- **Geometric.** The region within which a spatial observation lies.

The report goes on to emphasise that it is particularly important to ensure that, in attempting to represent uncertainty, artefacts are not introduced that "obscure, clutter, or interfere with the information to be displayed." (69)

Visualisation approaches that have been used for representing uncertainty fall into two general categories: (69)

- intrinsic representation techniques that integrate uncertainty by varying the appearance of the data (e.g. shape, texture, brightness, opacity and hue); and
- extrinsic representation techniques that add geometry to describe the uncertainty (e.g. arrows, error bars and charts).

The choice of visualisation approach depends on the nature of the uncertainty and the application context. For geospatial contexts, five intuitive categories of uncertainty representation have been suggested by the report: (69)

- modification of graphical attributes, such as colour, texture, blurring, and opacity;
- addition of artefacts, such as glyphs, contours, and iso-surfaces;
- animation of graphical attributes to illustrate the expected variability
- non-visual techniques, such as acoustic and haptic feedback coupled with the visual display
- user interaction, such as information pop-ups on mouse hover over a data feature.

Most Interesting in the report are the observations that The decision times for experienced users of the data and visualisations were not affected by uncertainty, but those of inexperienced users were significantly increased. (69) Conversely, the was improved decision making performance for uncertainty visualisation for relatively easy tasks, but not for more difficult tasks where other considerations might dominate. (69) This has considerable application when considering the use of uncertainty visualisation for combatants as opposed to commanders. Training in the use of uncertainty visualisation appears to be the key to taking advantage of the uncertainty knowledge, and it might best be applied at the combatant level for knowledge advantage in combat?

Another study (24) indicated that the cognitive burden on the subjects' memory, attention, and workload were significantly diminished when using the uncertainty visualization interface, in contrast to when the test subjects used the standard interface. Subjects were able to complete tasks in less time, and with a higher accuracy rate. Further, the subjects perceived that they operated more effectively when using the uncertainty visualization interface, in contrast to when the subjects used the standard interface. (24) (Pp82) When looking at displaying uncertainty by visual means, one also needs to consider the level of command, the environment of the user and by what prism is the user viewing both the data and the degree of uncertainty (e.g. written, 2D display or 3D display, haptics).

This research supported the hypothesis that adaptive uncertainty visualization significantly reduces a user's cognitive load in an environment where both stress and uncertainty are abounded. This has clear implications for military situations where combatants are subject to high cognitive load.

Visualisation Assimilation

Another aspect affecting the performance of the military task is the amount and quality of the visual input, as well as the resultant visual perception and cognitive performance. (70) Visual perception is defined as the "*mental organization and interpretation of the visual sensory information with the intent of attaining awareness and understanding of the local environment, e.g., objects and events.*" (70) *(Pp335).* Cognition refers to the faculty for the human-like processing of this information and application of previously acquired knowledge (i.e., memory) to build understanding and initiate responses. (70) Cognition involves attention, expectation, learning, memory, language, and problem solving (70). This study (70) explains that there are "*important visual processes that contribute to visual perception and cognitive performance. These include brightness perception, size constancy, visual acuity (VA), contrast sensitivity, colour discrimination, motion perception, depth perception and stereopsis*." (70) (Pp335).

A 2018 study focusing on cognitive data visualisation (21) provides another perspective with an examination of embodied cognition and ultra-rapid visual categorisation. (21)(Pp16) Embodied cognition is seen as the reason why processing information presented in forms that are not present in nature takes more time and are not straightforward to interpret. (21)(Pp17) Ultra-rapid visual categorisation is the ability to observe and assimilate to a decision, with humans able to decide whether a briefly flashed image belongs to a target category or not in under 400msec (underlying processing in 150msec). (3) (71) Torok and Torak postulate "*that carefully designed two dimensional graphs may take more time to process than a more natural three dimensional scene*." The Toroks undertook several studies investigating ultra-rapid visual categorization, that consistently found that complex natural scenes displayed for milliseconds can be categorized in under 150msec. Further studies showed that people can process even multiple scenes concurrently in parallel at this speed, which means that no directed attention is required. Ultra-rapid categorization of complex natural scenes is highly automatic and is not affected by the familiarity of the exact pictures. (21) This clearly indicates that the visual system is adapted to the complexity of the visual world; consequently, the natural-unnatural dimension is far more important in perception than the simple-complex one. (21)

In essence, the human brain can rapidly assimilate complex data presented visually in natural 3D forms than significantly fewer complex data presented in non-natural (i.e. graphs etc) 2D forms. The brain can even do this with multiple complex natural shapes simultaneously. This is the reason why 3D visualization has spread so quickly in engineering design and medical imaging. In both cases the target data is three dimensional. Therefore, using 3D for the representation means no significant spatial information loss. (21)

Torok and Torok also looked to visualisation as having vital importance in future human-computer interaction (HCI), where the rapid development of artificial intelligence (AI) urgently requires more effective interfaces than the obsolete existing ones. New visualizations developed on existing empirical research of human cognitive processes showed the interaction with information and spaces, interactively generated by AI, can be more effective. Based on neuropsychological research findings cognitive design can effectively influence pre-attentive visual processes.

The effect of colour in human perception and visualisation processes

Qualifying this is that human vision is a product of both biological and cultural evolution. Colour plays an enormous role in the human perception (visualisation). The more complex the data, the more important colour is in guiding the observer in visualising the data. Careful selection of colours can show a wide range of distinguishable sections within continuous data, even when a small set of hues is utilized. (22) Cognizance also needs to be taken of the fact that not all combatants will be able to discern the full range of colours (colour blindness), though Tier 1 (Specialist) and Tier 2 (Mounted and Dismounted) Combatants in the Australian Defence Force are mandated to have a high Colour Perception (CP) rating.

Some colours clash with each other (e.g. blue/green, yellow/orange, blue/magenta, cyan/yellow). This can make perception difficult for the human brain. (23) Each colour is also said to have its own unique value, or level of "greyness." If two colours are similar in their levels of greyness, as in *Figure 11* below, then the contrast appears too low. Therefore, it can be difficult for someone with vision problems to differentiate between the two.

Figure 11. Colour Contrast Example
(Courtesy of 5AM Solutions Inc)

An Integrated Digital Soldier System

Overview

The Integrated Digital Soldier System (IDSS) construct is a concept for dismounted and mounted land combat in the 5th Generation warfighting environment. This concept seeks to enhance the role the ground combatant as a sensor and node, leveraging technological advances to improve SA and agility, 'remote lethality' and protection.

The enhanced land combatant will interface with manned and unmanned ground vehicles to be at the forefront of warfighting in what can be described as the Knowledge Centric Warfare (KCW) environment. (72)

Background

For context, the warfare paradigms in the 20th and 21st Centuries may be described as follows:

- **Platform Centric Warfare (PCW):** predominately occurs in the physical domain;
- **Network Centric Warfare (NCW):** predominately occurs in the physical domain with parts in the information domain;
- **Information Centric Warfare (ICW):** predominately occurs in the information domain with part within the cognitive domain; and,
- **Knowledge Centric Warfare (KCW):** predominately occurs in the cognitive domain. (72)

Platform Centric Warfare

The conduct of major nation states warfare has evolved significantly over the past century. The First World War's massed infantry and artillery tactics drawn from the European wars of the 19th Century were dramatically changed in 1917 with the introduction of "infiltration" tactics, initially by the Germans, but then adopted by the other belligerents after consideration that their previous tactics were not effective, irrespective of the men and materiel. (73)

These tactics were then expanded by the extensive use of aircraft and armoured vehicles of the Second World War. The Second World War saw the use of massed bomber formations, whose use was then overtaken by a single aircraft with an atomic weapon. The threat of atomic warfare saw devolution back to infantry, artillery and armour pre-eminence in the Korean War, with aircraft formations now at 4-6 aircraft rather than massed fleets. In Vietnam and the Russo/Afghan War warfighting devolved again to dispersed Battalions with supporting armour, supported by 1-2 fixed wing aircraft and large fleets of helicopters. (72)

The Middle Eastern Wars (Israeli/Arab 1948/1956/1967/1973/1982/2006), the First Gulf War (1990/1991), and the Second Gulf War (2003) saw the use of armoured infantry and armour in major formations. The only exception being the bloodbath of the Iran/Iraq War of 1980 to 1988. (74)

These conflicts may be considered PCW paradigm. (72) A common element in PCW is the manner in which information (intelligence) played a role. Data was collected by individuals, small groups, reconnaissance, signalling devices (listening and recording by various means), aircraft photography and (later) satellite imagery. This information was then collated at various headquarters and disseminated in written reports and photographs that were then transported by courier, aircraft and signal.

Network Centric Warfare

The advent of NCW saw an evolution in the methodology of warfare. Network-centric warfare is built around human and organizational behaviour – a way of thinking in terms of linkages. Its end result is combat power that can be generated from the effective linking or networking of the warfighting enterprise. (72)

Examples of NCW are the Counter Insurgency (COIN) conflicts in Iraq and Afghanistan from 2011 through to the present day, which have seen warfare again devolved to dispersed Battalions with supporting armour, supported by 1-2 fixed wing aircraft and large fleets of helicopters. Information (intelligence) collection leapt forward with the advent of digital technologies. These technologies have been able to gather, assimilate and distribute mass data. The means of processing this data, by machine and/or human, has struggled to keep up (4), as has the means to transmit the raw data in the first instance.

Information Centric Warfare

The recent peer/near peer conflicts in the Ukraine and Georgia are examples of ICW. The Russian Military has long shown an interest in moving towards an ICW methodology. Russian annexation of portions of Georgia (South Ossetia and Abkhazia) in 2008 and the Ukraine (Donetsk and Luhansk) from 2014, have been a mixture of hard and soft power in what has also been referred to as non-linear warfare. This included the use of information to manipulate individual thinking and manage social networks. The Russian integrated approach sees the information space at its centre, so that "the most diverse, unrelated ideological, social, civil, economic, ethnological, migration processes are manipulated by external operators in order to achieve specific goals." (75)

Knowledge Centric Warfare

The progression to KCW will see the span of conflict expand beyond ICW, with each combatant being a node and a sensor. Each node is synchronized with its fellows in a decentralised mesh with the use of AI, machine learning and smart algorithms to process the "big data" into knowledge. Whilst this is an end in of itself, presentation of the information as knowledge is the next step. As previously described, presenting the extraordinary breadth of knowledge that can be accomplished with AI can only be accomplished with visualisation. With each node (individual combatant and upward) capable of assimilating vast data if presented visually, SA and the capability to respond in a rapid fashion increase significantly. The combat force accelerates the OODA Loop (observe, orient, decide, act). (76)

As the "Digital Age" advances, the ability of belligerents to gather data has increased exponentially. This sees warfare developing into the KCW era. The F-35 JSF is the powerful and comprehensive integrated sensor package of any fighter aircraft in history. (37) Combined with EA-18G Growler, P-8A Poseidon, E7A Wedgetail and MQ-4C Triton, as well as the RAN's new DDGs and FFGs, the ADF possesses unparalleled data collection capabilities. Where the

ADF is struggling is the ability to assimilate this enormous amount of data into actionable knowledge.

The RAN and RAAF are well advanced in this realm with the supporting technologies and entry into the U.S. Department of Defence' intelligence broadcast network (the Integrated Broadcast Service or IBS), which commenced development in 1994 and continues today. The IBS integrates multiple intelligence broadcasts into a system of systems, and migrates tactical receive terminals into a single, related Joint Tactical Terminal (JTT) family. The goal of the IBS is to resolve the uncoordinated proliferation of "stove-piped" intelligence/ information broadcasts by providing the tactical commander with integrated time-sensitive tactical information. (77)

The ADF is seeking to develop an IBS functionality, through Joint Project 2065 Phase 1 (JP206 Ph 1) that will see the establishment of an Information Management Element (IME) which correlates and bridges information between a number of computer networks, satellite links and real time tactical data links. This capability will form an important component of the ADF's Tactical Information Exchange (TIE) Environment while concurrently supporting closer allied interoperability. The Proof of Concept (POC) functionality Initial Operational Capability (IOC) is not scheduled until at least FY 2018/2019 to FY 2019/2020. JP2065 Ph 2 will further extend the Phase 1 capability by upgrading the Australian IBS to maintain compatibility with allies, introducing new system capabilities and extending the ADF roll-out of the system. (78)

The Australian Army and KCW

The Australian Army is not as well established in this realm as the other two services. Even with the (relative to RAN and RAAF) data collection systems available, there are significant shortcomings in collecting and transmitting the raw data, analysing and storing the data, and conveying the data as knowledge to combatants and commanders.

Advances with the introduction of the ELBIT Battle Management System (BMS) under Land 200 for both the Battle Management System - Mounted (BMS-M) and Battle Management System - Dismounted (BMS-D) have seen the devolution of information increase significantly in a visual format. The ability of the current communication architecture to sustain much more than data transfer is highly constrained, with difficulty transmitting more than small still images.

Added to this is a reported lack of enthusiasm for the BMS-D amongst front line personnel. (79) This is further compounded by the additional comment in the ANAO Report that:

"*The BMS-D have the following safety issues:*

- Electromagnetic interference / Electromagnetic compatibility emissions / Radiation hazard

- Weight

- Size

- Premature fatigue."

The Defence Industry Daily cites the Australian National Audit Office (ANAO) report of 2012/2013 Major Projects as follows"

"The user community do not accept and use the BMS-D." This is normal for initial "Infantry-21" systems, which often create issues with carry weight, required power, and tactical awareness. Australia is looking at the possibility of changing its entire specification set. They're

looking for ways to reduce size and weight and are wondering whether a tiered BMS-D system that can add and subtract items based on mission needs would be feasible or helpful. Of course, it's a military, so they also talk about emphasizing doctrine and "human ergonomics training," which amounts to "try and force troops to use it." (80)

The issues of weight and power can and will be overcome as technology improves. The issue of knowledge assimilation for SA won't improve whilst the method knowledge presentation is a handheld tablet device with 2D imagery.

Discussion within the Professional Military Community is also mixed. Recent articles on "The Cove", (81) (82) outline here different points of view on the introduction and value of the BMS-D. Ben McLennan in his article titled 'BMS-D: The Missing Link" states that the "soldiers and junior leaders from 3 Brigade who recently tested the emerging BMS-D hardware and software concluded the form and design is ready - and now." (81)

McLennan further states that he believes BMS-D offers the Australian Army a circuit breaker *"to truly realise our warfighting pillars, methodically and responsively, whether we fight mounted or dismounted. It will unhinge the enemy's ability to dislocate. It is the missing link to enable true tempo and reconnaissance pull, optimise combined arms teams (mounted/dismounted), allow us to rapidly perceive and target the enemy's Centre of Gravity (down to platoon/troop and section levels), attain surprise more readily, better inform commitment of Main Effort and Reserves, enable deception at all levels – as well as allow all to judge the success of such deception, and maximise joint fires and effects. Realising these principles will enable true application of the manoeuvrist (sic) approach and mission command throughout our fighting Formations."* (81)

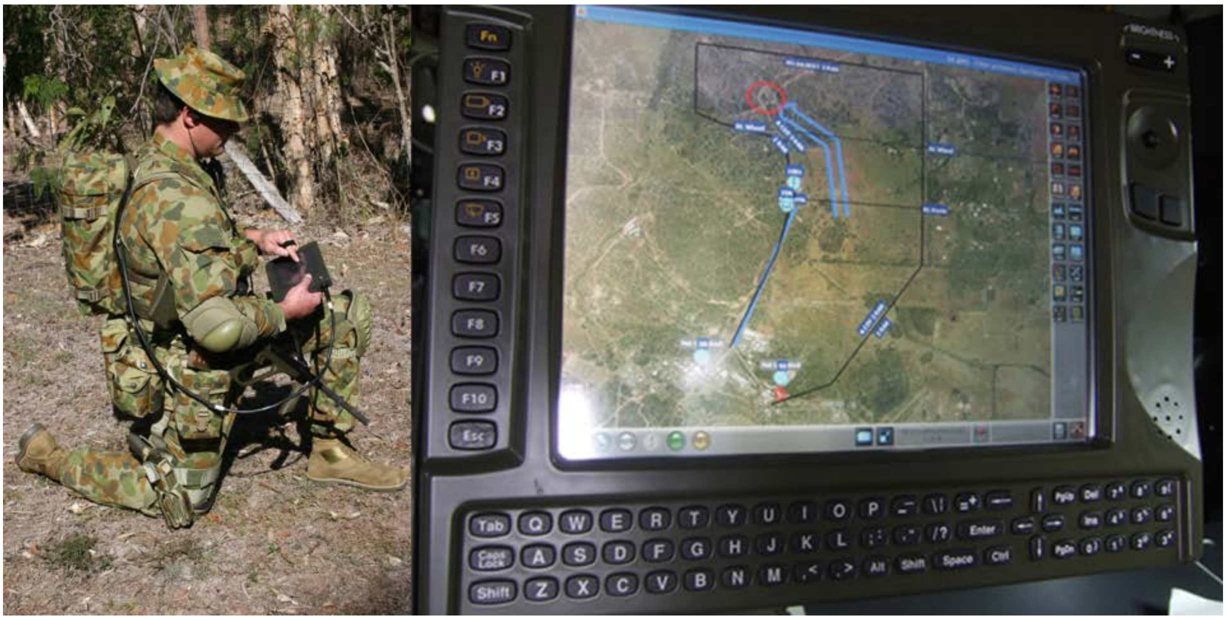

Figure 12. Elbit BMS-D and BMS-M
(Courtesy of Elbit Systems Australia)

In a response to McLennan's article, (83) by William Leben, Leben queries "*how commanders, particularly junior commanders outside of formation headquarters, perceive the battlespace*." (82) He contends that the situational perception, at a tactical level is overwhelmingly visual. (82) Further, he argues that, for junior commanders, it is not tactically advantageous to devote any significant portion of their time, during a tactical action, to interacting with a battle management system. Leben goes on to state that "*it is not at all clear that BMS-D is a key part of that innovation*." (82)

A comment on McLennan's article by 'Dan M' (83) postures "*whether pervasive (and invasive) BMS is the panacea to these problems*." (83) Another reviewer 'Paul M' discusses the ability to perhaps 'detune' the BMS interactions between the subordinate units and higher HQ by utilising the in-service Harris radio (84) to provide location updates only rather than the comprehensive management outlined by McLennan.

Intent

The IDSS is conceived as an enabler for a new concept for close combat in the environment envisaged for KCW in the 21st Century, where multi-spectral sensors, AI, Deep Learning Neural Systems and semi-autonomous/autonomous weapon systems will have primacy.

The IDSS concept seeks to leverage legacy and new technologies, gaining advantage primarily through integration of existing and emerging technologies, and in doing so mitigate risk to the best possible degree. The IDSS is a technical construct of synergistic technologies and systems that are both enabled by, and enablers for, a myriad of other system components. The IDSS is a system of systems of systems, where integration is the key. See *Figure 13* below.

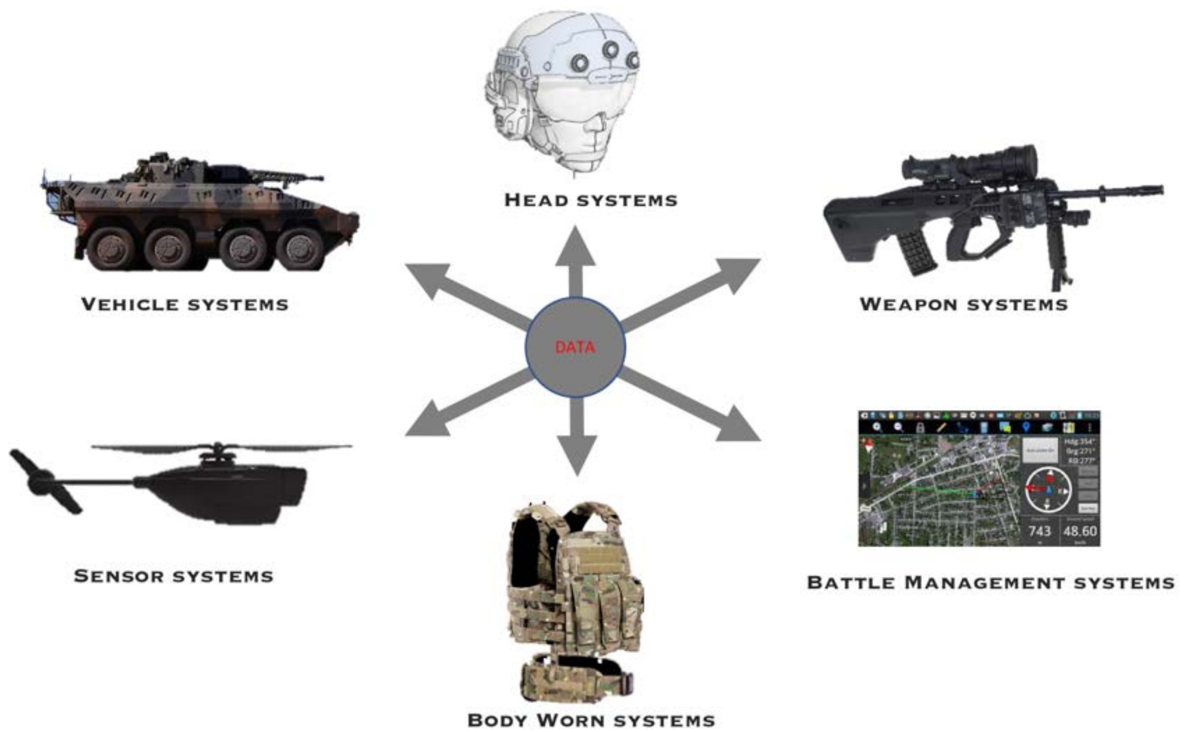

Figure 13. A System of Systems of Systems

The fulcrum of the IDSS is the Gentex Corporation's[1] Integrated Digital Helmet System (IDHS), currently under development, funded by CTTSO, PEO Soldier & US SOCOM. The IDHS is an enabler for a range of new Capabilities, including:

[1] Gentex is an OEM of the ADF's in-service dismounted, CVC, rotary wing, fixed wing & F-35 JSF helmets. The IDHS borrows extensively from these systems.

- **A heads-up common visualisation of data as an augmented reality.** Visualisation would take advantage of 3D displays in complex natural models to aid assimilation in high stress or high tempo environments. Areas to develop include inculcating associated uncertainty assessment and realization into the display.
- **A common digital sensor, node and platform on the battlefield forward edge.** An individual sensor suite (helmet vision, weapon sight, gunshot/UAV detection, CBRN detection) that feeds into the big data IBS collection methodology for AI processing to derive battlefield knowledge for passage to close combatants as visualised knowledge for shared SA.
- **A full immersive simulation head piece across individuals, vehicles and platforms.** Through containing all of the senses of the combatant within the IDHS, the ability can be realized to stimulate the five senses for simulation of any environment. This is further expanded by use of AR to create a fully interactive combatant environment.
- **An enabler for voice / gesture activated menu and application-based systems.** The Army has been constrained by the requirement for ruggedization and certainty in operating equipment. The advent of digitisation, miniaturisation, gesture controls and voice recognition can be enabled through the IDHS.
- **A platform for physiological data management (PDM) systems.** The IDHS can provide a reliable, functional, powered sensor and node for the collection and dissemination of PDM data.

Within the IDSS "System of Systems" approach, all systems are enabled by, and enablers for, the others, but the IDHS is the fulcrum.

The IDSS will provide a combat edge to the Australian mounted and dismounted combatant:

- by gathering, synchronizing, sharing and visualising digital knowledge, while
- leveraging AI, machine learning, smart algorithms and deep neural computing applied to "big data" to create knowledge, while
- using integrated extant and developing systems, and
- through knowledge visualisation at the forward edge of the battlefield area, to
- achieve capability overmatch in a contested environment.

Concept

The IDSS is also a concept of tactical warfighting in the contested ground environment that leverages knowledge to augment the combatant's abilities. The concept revolves around the integration of all components of the land force sharing data to create knowledge. This creates a force multiplier effect whereby the sum of the knowledge of the individual combatant is equal to the sum of the knowledge of the collective adversary. This is made possible by each combatant node (individual, vehicle, UGV, UAV, aircraft or maritime vessel) collecting data from the span of conflict (land, air, sea, cyber and space) for assembly, storage, analysis, presentation and dissemination back to the nodes as visualised knowledge.

The keys to the concept are:

- data distribution, and

- data visualisation.

These keys are supported by the following pillars:

- the introduction of digital sensors at all nodes of the force;
- the ability of dispersed “knowledge nodes” to assemble, store and analyse the data, synchronizing with other “knowledge nodes” within the force; and
- the ability of the nodes to present knowledge, in an appropriate fashion, via visualisation.

The network of nodes and sensors contribute to the greater joint and combined whole, generating and receiving data to create knowledge.

Considerations

Some of the considerations in the development of the concept include:

- **Combatants as sensors and nodes.** Combatants currently gather and share little in the way of digital data. The use of tubed image intensification (I^2) on either the head or weapon benefits only the individual user, with no ability to share or otherwise process this data. Adversary locations are reported via voice or text using digital radios and BMS. Imagery is difficult and time consuming to acquire and distribute. Whilst Soldier Personal Radios (SPR) act as nodes in the sense of throughput of the data above, apart from the BMS, there is little nodal functionality. Combatants must be able to “vacuum up” data as distributed by sensors at all times. “Meshing” provides additional context and reinforcement to the validity of the data.
- **Accelerating decision making through data distribution & visualisation.** Warfighting in the “Knowledge Age” (72) requires overmatch of an adversary not just through firepower, but more importantly via decision making (the OODA Loop). To achieve an overmatch in decision making, the maximum data (raw intelligence) must be able to be not only collected, but also transmitted for processing. Once transmitted the data must be processed to derive knowledge. This can be achieved by leveraging AI, machine learning, smart algorithms and deep neural networks applied to "big data". Knowledge can then be pushed out as required to the Forward Edge of the Battle Area (FEBA) as data visualisation for rapid assimilation by end users.

  In 1992 a total of 100GB of data was generated globally per day. By 2018 it is estimated approximately 50,000GB of data will be generated globally per second (4320 Petabytes per day), with data storage growing at 4x the world economy. (85) As such, the challenge lies in identifying the relevant knowledge needle amongst the information haystack within the parameters of the specific mission requirements.

  With the data harvested by Communications, Surveillance, Intelligence and Reconnaissance, Space, Electronic Warfare, and Cyber Security assets, combined with data from individual battlefield sensors (individuals, vehicles, tactical UAV), there is the unparalleled opportunity to aggregate and process this data into battlefield knowledge which can then be visualised for cognitive assimilation and decision making (OODA).

  Rapid, accurate and continuous knowledge to enable Decision Superiority against an evolving, agile, amorphous, and often asymmetric threat, is a key consideration in defeating adversaries who are undertaking the same evolution. However, to deliver tactical advantage to close combatants, this information must be translated into knowledge.

Where information is provided unfiltered, and ‘en masse’, to tactical elements this will rapidly result in incorrect interpretation, disorientation, information overload, unsound tactical actions, and/or decision paralysis.

Humans alone are unable to process the vast quantity of information generated, whilst conventional processing machines, whilst faster, have limited utility in analysing intuitive linkages between data points and comprehending trends and patterns.

- **Leveraging individual systems as enablers to enhance the whole.** Each (current) component of the proposed IDSS is a brilliant technology in and of itself. When combined with other technologies, the effects are amplified. For example, In the Mouth (ITM) transceivers are game changers in delivering clear articulation and enunciation on the battlefield, irrespective of ambient noise. In doing so they also enable the introduction of voice recognition software that would otherwise be unable to function within the battlefield due to the exigencies of battlefield noise.
- **Rapid advances in technology.** The advent of AI, quantum computing, nanotechnologies and deep neural networks will continue to evolve technology at an exponential rate. Whilst Moore’s Law (86) is ascribed to transistors in a dense integrated circuit, the advent of nanoscale transistors and InGaAs transistors has maintained the progress of the theory. Other technologies that are advancing rapidly include developments in portable power storage and generation. Solar power and development of new Lithium Ion Silica formulas that double battery output by weight and volume are only a taste of what is coming.
- **Peer/near peer threats.** The rise of China and the threat of the Thucydides Trap (87) may see Australia involved in a peer or near peer (either by proxy) conflict. Whilst recent conflict has been low scale intensity, an unwillingness to prepare for and fight a peer threat will either see Australia unwilling to commit to National undertakings or face devastating consequences in doing so. Australia should seek to be at the forefront of technology, not just in the air and sea domains, but also land, space and cyber.

The People’s Republic of China (PRC), and in particular the Peoples’ Liberation Army (PLA), see three major transitions as key to its modernisation. These are:

- o A focus on Anti-Access/Area Denial (A2/AD) (88) objectives;
- o Power project capabilities; and
- o A drive to develop AI infused platforms and systems to exploit these for conflict and military capability. (13)

Russia is also focused on the same attributes (89), and these have been clearly demonstrated in the Ukraine and Georgia. Georgia in particular has been the target of the full spectrum of hybrid tactics that Russia currently deploys in Ukraine and elsewhere. (2)

Even “Near Peer” potential adversaries possess advanced UAV systems and signature detection systems. Over 100 countries possessed UAVs around the world, in addition to a range of non-state actors, including Hamas, Hezbollah, ISIS and Yemeni Houthi rebels.

(12) The Asia-Pacific is the next most active market by region after the US by both the number of air vehicles produced and by the value of those air vehicles. (90) As of June 2017 sixteen countries possessed armed drones. It is estimated that this figure is now more than thirty. Countries include the PRC, Egypt, Iran, Iraq, Israel, Jordan, Kazakhstan, Myanmar, Nigeria, Pakistan, Saudi Arabia, Turkey, Turkmenistan, United Arab Emirates, United Kingdom (UK) and the USA.

Whilst some have developed these themselves, over 90% of international armed drone transfers have originated from the PRC. (12) One should note that a number of these countries lay within the Asia Pacific or within regions Australia has recently operated in.

- **Common mounted, dismounted & crew soldier combat ensemble.** Plan Beersheba commenced the transition of the Army to a mixture of mechanised, motorised and light infantry battalions, resulting in a significant number of combatants assuming dismounted, mounted and crew roles in short succession. With the introduction of technologies under the IDSS that facilitate in seat power replenishment and data connectivity, commonality of combat ensemble and agnostic seat interfaces will enable significant cost, time and effort savings.

- **Agnostic Generic Soldier Architecture (GSA) & Generic Vehicle Architecture (GVA) integration.** The Australian Army, through the auspices of the Land Network Integration Centre (LNIC), are continuing to develop a GSA (modified to be the Australian Soldier Systems Architecture or ASSA) and a compatible GVA, along the lines of similar work by the United Kingdom Ministry of Defence (UK MOD). IDSS compliance with the ASSA and GVA will enable full integration both ways (combatant/vehicle and vehicle/combatant) for the evolving system.

- **Accommodating extended use of soldier combat ensemble in, and integration for, Australian combat vehicles.** Many studies have been undertaken to assess and mitigate the effects of long-term exposure to wearing SCE. However, research regarding wearing SCE for long periods of carriage in a military vehicle is lacking. Issues of micro and macro vibration inherent in vehicle operation, in addition to inertial amplification of load carriage on the spine and lumbar region, need to be addressed and considered in the design of an IDSS.

- **Transition from analogue to digital sensor systems.** Current soldier borne sighting systems and night vision devices NVD are primarily analogue. The exception is the Elbit XACT th65 Thermal Night Weapon Sight (91), which was purchased with the digital vision output as part of the system for "future proofing". The L3 PVS-31a Night Vision Binoculars are analogue I^2 tubes and have no capacity to capture or share vision as data.

- **High speed distribution of data across nodes & platforms.** The current Harris Falcon iii ANPRC152a Wideband Networking Handheld Radio (84) supports high speed distribution of data, including video, using ANW2 or SRW waveforms, which both support video, if configured.

  The Persistent Systems MPU5, (92) in service with Special Operations Command (SOCOMD) is also efficient Mobile Ad Hoc Networking (MANET) radio systems. Streaming data, video, voice as a fully integrated Android™ computer system makes the MPU5 the world's first Smart Radio.

- **The UK "Fight Light" concept.** The United Kingdom's Ministry of Defence's Dismounted Close Combat Load Carriage "Fight Light" concept closely examined the (UK) soldier's physical load's impact on issues of lethality, survivability, agility and, in particular, cognitive ability. This has been also examined by a range of other UK MOD studies from the UK's Defence Science and Technology Laboratory (DSTL). (20) (93)

  These studies have shown that overall survivability on the battlefield is more closely aligned with higher levels of agility than higher levels of protection. The "Fight Light" examination provides a very strong rationale for significantly reducing the load of the close combatant to a maximum of 25kg in marching order and <25kg in the assault. Whilst this may sound impractical in this day and age, the evidence supports the prioritisation, in ascending order, of cognitive ability, agility, lethality and survivability for the close combatant.

  Effective warfighting for the Australian close combatant must take place in a paradigm in which the combatant fights with a significantly reduced load than currently is the case. Cognitive ability and agility in the battle are the keys at the tactical level.

  It is of no importance seeking operational tempo, reconnaissance pull, combined arms teams, focusing friendly action on enemy centres of gravity etc. (83) if the close combatant or commander is too exhausted or too overburdened to fight the battle. Having marched in with 60kg on his back or sat in an armoured vehicle with a vibrating (11) 20-30kg of equipment bouncing up and down on his spine, will create a dead feeling in is legs and numbness of the shoulders and lower back. (5) (94) (51) (53)

  The fact that the Australian Army has always prided itself on its ability to carry heavy personal loads over long distances does not justify the continued burden placed on soldiers expected to fight to the best of their ability, particularly when generic loads can reach 70.2kg. (20) "*The Soldier cannot be a fighter and a pack animal at one and the same time, any more than a field piece can be a gun and a supply vehicle combined. The idea is wrong at the start. Yet it is always being repeat*ed." (19) (Pp19).

  If nothing else, given the concern in the ADF about Traumatic Brain Injury (TBI) blast monitoring and mitigation on operations (95), the long-term effects of excessive load carriage, against the findings of numerous studies that, it is not only detrimental to the health of the individual, but also against tactical warfighting sense, would make it an imperative?

- **Advanced human/machine user interfaces**. To date the use of advanced human/machine user interfaces such as voice recognition, gesture control and biometric security have been constrained in the deployed military environment compared to the civilian environment. Primarily this has been a result of the comparative difference in technology sets and partly that the military environment has its requirements for ruggedization and constraints such as emissions, noise and security.

  With the advent of digitisation, and in particular the introduction of digital sensors (night/thermal vision, acoustic detection, PDM), and the advance in deployed computing power, this will change. The introduction of ITM transceivers, for example, will enable the production of clear articulation and enunciation irrespective of ambient noise. Whilst this is a great step forward in and of itself, it will also be an enabler for voice recognition software on the battlefield. Similarly, the introduction of gesture controllers, where these can interface with embedded software and digital vision systems to introduce intuitive natural gestures to control systems and software (i.e. flying UAV or controlling UGV). (96)

- **Human physiological performance management.** The Australian Army currently determines work rates (e.g. defensive entrenchment tasks) via a table of activity types that are predicated on temperature ranges, humidity and attire, per Figure (97). These 'Work-Rest' tables are based on the lowest common denominator of combatants, with additional margin to account for error. (98)

  These tables are designed to provide guidance to commanders in the field on maximum work rates in various environmental conditions to avoid issues of heat stress and heat stroke. (98). Soldiers not in the field already use a range of PDM, such as Apple's iWatch™, FitBitz™ etc. These devices sense, record and analyse various aspects of physical exertion, including heart rate (HR) and heart rate variability (HRV), respiration rate (RR), core body temperature (CBT), Blood/Oxygen mix (VO2 Max), distance, elevation and speed.

  More sophisticated devices (99) with non-invasive sensors (in-ear, internal) are able to derive more precise data such as:

  - Core Body Temperature (CBT):
    - Heat stress indication
    - Physiological Strain Index
  - Heart Rate Variability (HRV):
    - Fatigue level monitoring
    - Atrial fibrillation (100)
    - Level of consciousness
  - Motion and actimetry[2]
    - Man down/fall detection (9 axis motion sensing)
    - Inactivity and posture monitoring
    - Distance monitoring

  With the addition of machine learning and smart algorithms a dynamic "envelope" can be created for each individual combatant, commencing at entry to the ADF. Each physical activity is recorded and analysed automatically, with data points including HR, HRV, RR, CBT, distance, elevation and speed. This PDM system "learns" the individual's data points and assigns them to health "envelopes" for ease of management. (99) These may include:

  - **"Green" envelope.** All physiological datum points are within normal parameters gauged against recorded norms for the individual, given ambient temperature, humidity, movement and orientation. No effect on cognitive ability should be evidenced.

[2] Actimetry allows the distinction between sleep and wake state [148], and it also offers sufficiently reliable information regarding sleep habits and sleep disorders of examined patients. (139):

- **"Orange" envelope.** All physiological datum points are extended beyond "green" envelop datum points but within normal parameters gauged against recorded norms for the individual, given ambient temperature, humidity, movement and orientation. Limited effect on cognitive ability should be evidenced. Caution should be observed, and physical exertion monitored.
- **"Red" envelope.** One or more physiological datum points are extended beyond "orange" envelope datum points beyond normal parameters gauged against recorded norms for the individual, given ambient temperature, humidity, movement and orientation. Effect on cognitive ability will be evidenced. The individual needs to be assessed by a competent person for signs of hypothermia, heat stress, heat stroke or other medical events (e.g. myocardial infarction). (101)

WBGT °C			Light Work		Moderate Work		Heavy Work		Very Heavy Work	
DPCU	Body Armour	MOPP4	Work/Rest (min)	Water (L/h)	Work/Rest (min)	Water (L/h)	Work/Rest (min)	Water (L/h)	Work/Rest (min)	Water (L/h)
<25	<22	<19	NL	¾	NL	¾	50/10	¾	30/30	¾
25-26	22-23	19-20	NL	¾	NL	¾	40/20	¾	20/40	¾
27-28	24-25	21-22	NL	¾	50/10	1	30/30	1	20/40	1
29-30	26-27	23-24	NL	¾	40/20	1	30/30	1	10/50	1
31	28	25	NL	¾	30/30	1	20/40	1	5/55	1
32	29	26	50/10	1	20/40	1¼	10/50	1¼	5/55	1¼
33	30	27	40/20	1¼	10/50	1¼	10/50	1¼	CM	1¼
34	31	28	30/30	1¼	10/50	1¼	CM	1¼	CM	1¼
35	32	29	20/40	1¼	CM	1¼	CM	1¼	CM	1¼
36	33	30	10/50	1¼	CM	1¼	CM	1¼	CM	1¼
≥37	≥34	≥31	CM	1¼	CM	1¼	CM	1¼	CM	1¼

Figure 5. Australian Army Work-Rest Tables
(Table Courtesy of Australian Defence Force)[3]

Unfortunately, civilian issued devices can also report the location of soldiers in the field. (102) This would seem to drive a demand for Military issued secure devices.

- **Personal Gunshot, UAV, UGV Detection Systems.** With the introduction of semi-autonomous weapon systems on modern armoured vehicles, working in conjunction with organic threat detection systems, the issue of personal gunshot detection systems should be considered and included in any future soldier system.

Whilst vehicle and static systems provide vehicles with a gunshot detection system, these have been too heavy for personal use. Lightweight meshed acoustic systems can provide a solution to the shortcomings of the crack/thump methodology of locating an enemy small arms threat.

Location data is then digitised and provided to the BMS. When this is derived from multiple sensors that are meshed to create, at a minimum, triangulation, then a significant degree of accuracy can be applied to the location of shooter/s.

[3] Wet Bulb Glove Temperature (WBGT)

There are several major benefits of a personal shot and UAS/UGS detection and location system. These are:

- o Notification of enemy threat over vehicle noise and other activity.
- o Immediate location of a shooter for close combatant orientation for cover.
- o Digital input of the (red) data to the BMS (and HUD).
- o Deconfliction with known friendly (blue) force locations.
- o The ability to generate dynamic data on enemy force elements as they shoot and move.

Providing this data from multiple sensors and nodes it must then be transmitted for processing to derive knowledge. Leveraging AI, but most importantly deep neural networks, this dynamic data can give indications of enemy tactical manoeuvre (advance, withdrawal, delay). This dynamic data can also be analysed with machine learning and smart algorithms (AI) over the wider schema to generate enemy activity mapping and likely movements/intentions to achieve an overmatch in decision making (the OODA loop).

- **Comprehensive force wide signature management.** Signature Management is one of Australia's Sovereign Industry Capability priorities. (103) Integrated battlegroup signature management systems, including decoy systems, are also one of Army's military capability objectives for Force Protection. (104) Signature management can take a number of forms but is primarily focused on the avoidance or delay in detection of persons, platforms, systems and command elements. Management implies coordination and integration, particularly across the diversity of Army's assets. The threat spectrum from near peer and peer covers from Ultra Violet (UV) through to RADAR per *Figure 14* below.

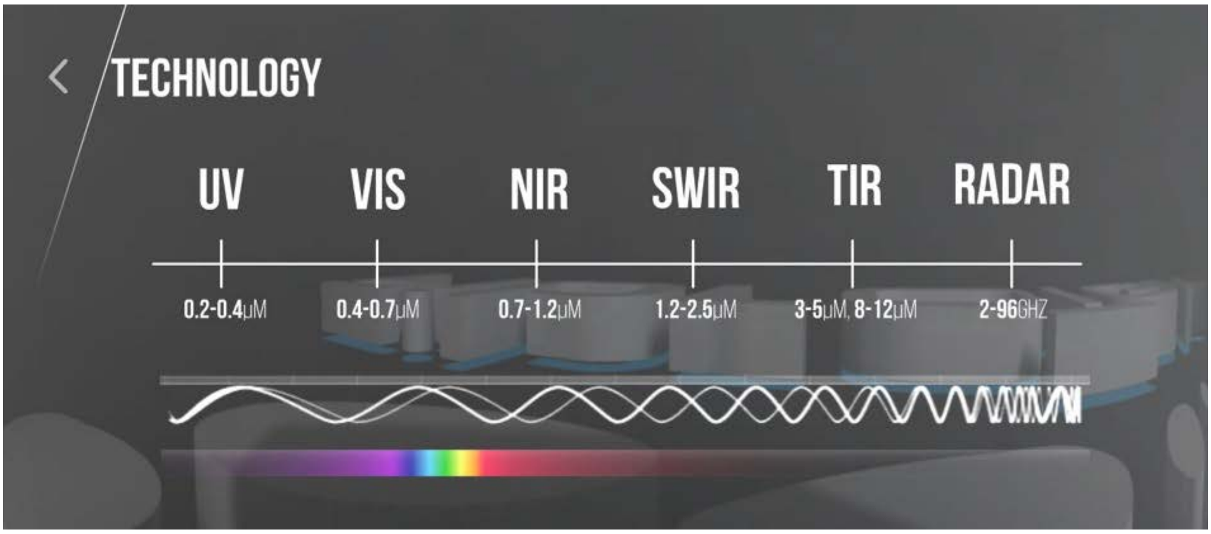

Figure 14. Signature Management Spectrum of Threat
(Image courtesy of Fibrotex USA)

In response to identified shortcomings in their current signature management systems (nets), and the development and fielding of new adversary threat sensors, the US Military went to a rapid Request for Proposals for a new Ultra-Light Weight Camouflage Net System (ULCANS) July 2017. Subsequently, an accelerated but comprehensive assessment of contenders, through a vigorous assessment process over multiple locations and environments worldwide, took place. (14)

In 2018 the Army has selected a 2D suite of products to provide it with the next generation of ULCANS. (15) The new ULCANS suite is be an all-weather, state-of-the-art signature concealment system that provides multi-spectral protection for troops, vehicles and equipment. See *Figure 15*, *Figure 16* and *Figure 17* below. The latest iteration, in a $500m US program, will replace the legacy woodland and desert camouflage variants developed in the 1990s. The new ULCANS suite will be developed in light and dark woodland, snow and alpine, desert, and urban variants. It will be expanded to be inclusive of personal, static and mobile applications.

Figure 15. Gun Position Signature Management
(Image courtesy of Fibrotex USA)

Figure 16. Vehicle and Static Signature Management
(Image courtesy of Fibrotex USA)

Figure 17. Ultralightweight Multispectral Reversible Signature Management
(Image courtesy of Fibrotex USA)

From the perspective of an IDSS concept, the current Australian Army approach to signature management for close combatants and ground forces assumes that there is no air threat, or at least air superiority. (105) Australia's current suite of camouflage nets are ageing and date primarily from the 1990s. In addition to this, the various vehicle acquisition projects (Land 121, Land 116, Land 400 etc.) did not include any requirements for signature management. Land 125 Phase 3 did not include personal signature management systems either, and Land 125 Phase 4 is not scheduled to consider “Passive Signature Management” until Tranche 3, currently scheduled for FY 2027/2028 to FY 2031/2032.

Brigadier Ian Langford, Director General Future Land Warfare (DGFLW), outlined in his presentation (48) some of the Australian Army’s shortcomings (relative to peers) in consideration of electronic warfare (EW) and electronic attack (EA). BRIG Langford also discussed Project Maven and the use of AI to identify adversaries by mining data that might be derived from UAV, satellite sensors etc. The US Military is fielding advanced computer algorithms onto government platforms to extract objects from massive amounts of moving or still imagery. (106) Personnel and computers will work symbiotically to increase the ability of weapon systems to detect objects, with an immediate focus on 38 classes of objects that represent the kinds of things the US Military needs to detect, initially focused on the fight against the Islamic State of Iraq and Syria (ISIS).

Project Maven focuses on computer vision, which is an aspect of machine learning and deep learning that autonomously extracts objects of interest from moving or still imagery, using biologically inspired neural networks and deep learning, defined as applying such neural networks (see *Figure 18* below) to learning tasks. (106) Technologies like Project Maven are designed to identify personnel (facial characteristics, weapons, uniforms, equipment), vehicles, facilities for targeting.

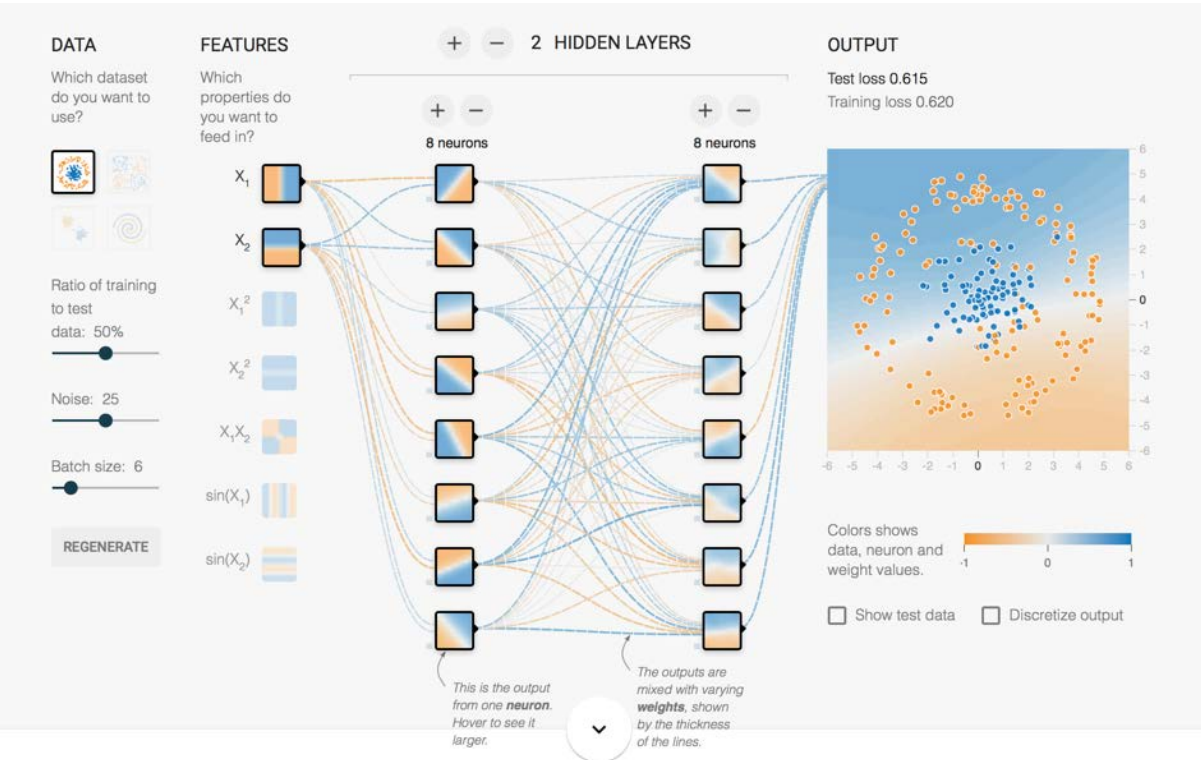

Figure 18. Neural Networking
(Image courtesy of Fibrotex USA)

Signature management for an IDSS will require comprehensive application, including personnel, weapons, vehicles and facilities. It will be of no use having masked vehicles and C3I nodes if unmasked personnel provide a pattern of life (POL) or activity based intelligence (ABI) (18) in and around the masked items. ABI is the analysis methodology for rapidly integrating data from multiple sources to discover relevant patterns, determine and identify change, and characterize those patterns to drive collection and create decision advantage. Unlike the traditional intelligence cycle, which decomposes multidisciplinary collection requirements from a description of the target signature or behaviour, ABI practitioners have advanced the concept of large-scale data filtering of events, entities, and transactions to develop understanding through spatial and temporal correlation across multiple data sets. (18)

When considering the option of infiltrating dismounted close combatants through rough terrain to gain a tactical advantage, one should also consider the thermal signal of a line of unmasked (limited or no signature management) combatants within the enemy's area of operation. Thus detected, by a thermal imager on a UAV, the swift application of fires would surely result in catastrophic casualties. Approach marches by night through rough terrain are therefore no different to approaching by day down a highway?

The methodology of these elements then gathering in an assembly area, then moving forward into a Forming Up Place (FUP), before lining up on the Line of Departure (LD) for an assault, would seem to invite annihilation in any sort of contested environment with any adversary remotely approaching a near peer? Perhaps "*Field Marshal Haig's supreme tactical plan (where the men climb out of their trenches and walk slowly towards the enemy...a plan they've used 18 times before)*". (107)

Figure 19. "Representative" Unmasked Close Combatants as seen from a TI enabled UAV
(Image courtesy of www.flir.com)

New wide-area persistent surveillance systems such as the Air Force's Gorgon Stare (108) pod-mounted sensor package can be used to track people and vehicles in city sized areas. Improvements in the proliferation of sensors (spectral diversity) that capture increasingly broad samples across the electromagnetic spectrum represent the most transformative and revolutionary advancement shaping the military today.

"*The WAAS system will support an end-to-end (collector to Service Processing, Exploitation, and Dissemination (PED) and/or tactical user) motion imagery based* *system for contiguous airborne wide area coverage of urban and selected environments with sufficient resolution and revisit rate to find, fix and track vehicles and individual dismounts within its field of view, day and/or night. The capability will enable concurrent near real-time SA, forensic analysis, and cross-cueing for other ISR sensors. WAAS data will support tactical users, commanders, and be globally disseminated to other nodes, inside and outside theater, including injection into Service PED architectures to support further phases of exploitation*." (108)

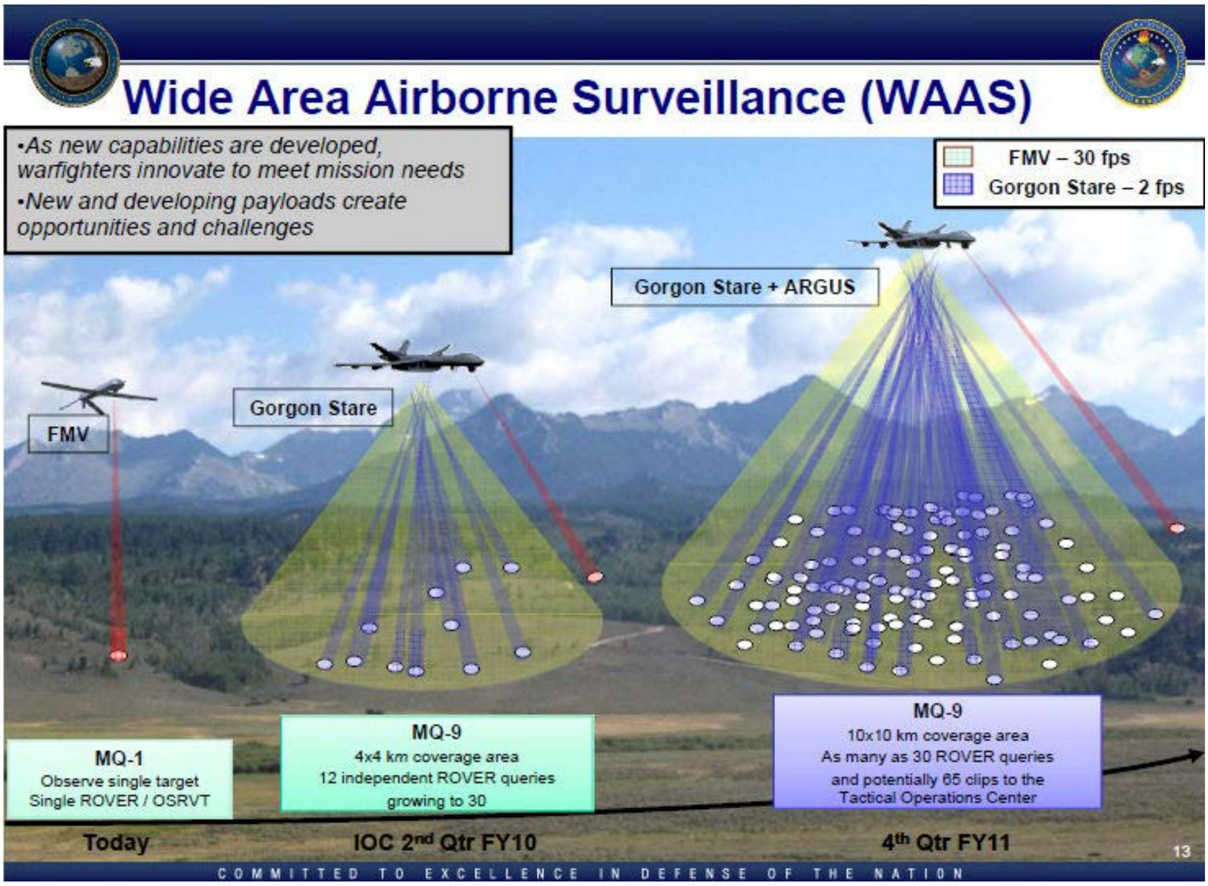

Figure 20. Gorgon Stare - Wide Area Airborne Surveillance (WAAS)
(Image courtesy of www.globalsecurity.org)

The US is not alone in fielding this type of capability and Australia should expect similar capabilities in conflicts with peer and near peer states now or in the future. The PRC has demonstrated "*a growing imperative to develop artificial intelligence-infused platforms and systems to fully exploit emerging trends shaping the future of conflict and military capability*." (13)

Another aspect of signature management is for small arms. Fighting asymmetrically in the future will involve deception and surprise as parts of an asymmetric attitude that refuses to accept conflict on the adversary's terms. Surprise is created when the adversary is unable to react effectively to our initiatives in time. Deception is created by measures that mislead the adversary. The use of signature management for the conventional forces small arms will allow Commanders at all levels to better achieve synchronised surprise and deception integral to efforts to generate shock and thus create desired effects.

> Use of small arms signature suppression for the entire land combat force allows for a wider dispersal of surprise by more elements of the combat team and can allow for extended period of uncertainty by the opposition as they attempt to locate the attacking force. Signature suppression on small arms is particularly useful in night fighting and close country operations, restricting the ability of the enemy to return fire effectively.
>
> Signature suppression on the entire breadth of Army's small arms would increase its capability to produce desired effects through the considered and coordinated use of both deception and surprise at the tactical and operational level, using both kinetic and non-kinetic means. Signature suppression enhances options for effects to support commanders at all levels, upon detection of a threat, to choose an appropriate method of response, utilizing deception and surprise. (109)

Visualisation

As previously described in this paper, close combatants and commanders at all levels struggle to process the amount of data received on the battlefield. The close combatant faces an ever-changing battlefield and a diverse and fluid set of tasks that must be performed. (70)

The battlefield environment is now generating more data than at any time in history, in diverse forms, and growing exponentially. Superior performance of these tasks is affected strongly by the amount and quality of the visual input, as well as by the resultant visual perception and cognitive performance.

Visual perception may be defined as "*the mental organization and interpretation of the visual sensory information with the intent of attaining awareness and understanding of the local environment, e.g., objects and events*." (70)

This melds with cognition which may be defined as "*the faculty for the human-like processing of this information and application of previously acquired knowledge (i.e., memory) to build understanding and initiate responses. Cognition involves attention, expectation, learning, memory, language, and problem solving.*" (70)

The perception of the world for the individual is essentially three dimensional. (21) The human visual system has developed to render the 3D information of the environment in the mind. This means we perceive depth information despite the 2D nature of the optical image on the retina and our perceptual system has adapted to the challenges of the physical world by converting the 2D imagery into 3D perception, embodied cognition. (21) This evolutionary development between our cognition and the environment makes us able to cope with the vast amount of (natural) information reaching our senses at any given moment and quickly react to new information in the environment. (21) Embodied cognition is the reason why processing information presented in forms that are not present in nature takes more time and are not straightforward to interpret.

By this reasoning, carefully designed 2D graphs take more time to process than a more natural 3D scene. Studies (110) consistently find that complex natural scenes displayed for milliseconds can be categorized in under 150msec as revealed by both Electroencephalography (EEG)[4] evidence and other tests. These studies also showed that people can process multiple scenes in parallel with this speed, which means that no directed

[4] An electroencephalogram (EEG) is a test used to find problems related to electrical activity of the brain.

attention is required. Additionally, ultra-rapid categorization of complex natural scenes is not only highly automatic but is not affected by the familiarity of the exact pictures. (21) This would seem to clearly indicate that the visual system is adapted to the complexity of the visual world; consequently, the natural-unnatural dimension is far more important in perception than the simple-complex one. (21) Information processing, when viewing a small 2D display, with abstract symbols, in a military environment, is not natural or intuitive. (111)

The assimilation of 2D symbology, as well as judgment of relations between symbols on a 3D display, can be an arduous task. The visual is the dominating modality for presenting information in military and civilian applications. (111) Although it is possible to present information using other modalities, seeing or vision modality will probably be a main modality for processing information in the future. A main concern is, therefore, how to create displays that are as visually intuitive as possible, on the one hand, and yet have the potential of integrating extensive information within one display without cluttering this, on the other hand.

As war fighting becomes more complex with the advent of new technologies (UAV, UGV, sophisticated sensors) there is a potential risk of information overload, where a combatant or Commander does not have the time to process, or make sense of, presented facts and circumstances. *"The presentation of information in 3D may therefore alleviate potential problems of information overload by integrating the horizontal and vertical views to one display which simultaneously presents information along the x-, y- and z-axes."* (111)

The rise of urbanization makes instability and conflict within dense population centres a very real possibility. (112) Close combatants operating in complex urban environments have a significant requirement for better 3D understanding of ongoing battle field situations. Displays that are compatible with the physical world, as well as the user's experience (18-30 year old combatant born in the digital age) are normally assimilated more quickly, accurately and thoroughly. (111) Compatible displays become even more advantageous under conditions with high workload or stress. (113) A proper well thought-out 3D visualisation is therefore particularly important for military applications where physical and mental stress is commonplace and constantly present. (111)

Uncertainty is also inherent in combat settings. In a combat situation, darkness may prevent a combat identifying friendly or enemy approaching. In an environment with such a high degree of uncertainty, decision-support systems, such as sensor/node networks, may make faulty assumptions about field conditions, especially when information is incomplete, or sensor operations are disrupted. Displaying the factors that contribute to uncertainty can make the decision-making process for a human operator, but at the expense of limited cognitive resources, such as attention, memory, and workload. (24)

Within the human/computer display, the introduction of uncertainty visualizations is seen as an adaptive approach which improves the combatant's decision-making process, without unduly burdening the operator's cognitive load. An adaptive approach to uncertainty visualization considers the cognitive burden of all visualizations and reduces the visualizations according to relevancy as the user's cognitive load increases. (24)

Another approach to improving cognitive ability and providing a capability edge is the use of individual variability as a Future Force Multiplier. (114) Some of the approaches that are included as "individual variability" may challenge traditional Military approaches but can offer great potential for increasing Army capabilities. Differences in behaviour, cognition, and performance of skilled tasks are highly individualised in the neural structure of combatants as much as differences in strength, stamina, height, or perceptual acuity are rooted in their physiology.

Neuroscience is establishing the role that neural structures play in the individual variability observed in cognition, memory, learning behaviours, resilience to stressors, and decision-making strategies and styles. Individual differences among soldiers can be leveraged to different military applications. These can then influence operational readiness and the ability of Army units to perform assigned tasks successfully. Individual variability is in many ways at odds with the conventional approach of training soldiers to be interchangeable components of a unit. (114) This approach may see roles within the team change depending on the operational environment and the ability of individuals to adapt and remain cognitive in a specific environment. Visualisation tailored to the individual, modified with uncertainty principles, role and circumstance dependent.

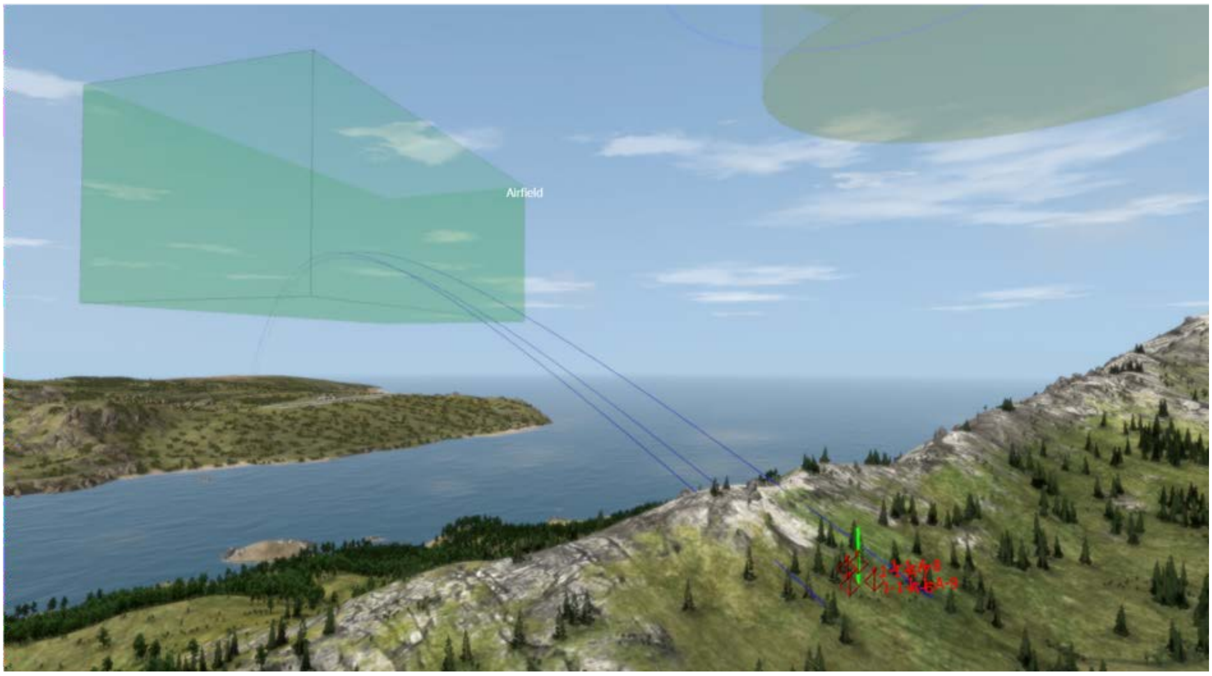

Figure 21. 3D Visualisation
(Courtesy of SimCentric Technologies)

Data visualisation (iconographic & 3D volumetric) therefore enables cognition and assimilation of massive amounts of data (collated, analysed and presented by AI) for SA, manoeuvre and targeting.

Data visualisation supports decision making, simplifying complex data into icons and volumes. The provision of complex natural 3D shapes facilitates significantly faster assimilation of complex data than unnatural fewer complex shapes. Assisting in this assimilation is the use of icons rendered in naturally perceived colour combinations and shapes that are more readily recognised & assimilated. These are:

- Green – positive/fully functional,
- Blue – friendly,
- Red – enemy/dangerous,
- Orange – warning/caution/attention, and

- Yellow – highlighted/data.

Visualisation of data in a natural form within an AR visor would seem to be the most efficient and effective means to provide the most comprehensive SA to the close combatant. Combined with multiple digital sensors, the ability to store, distribute and receive this knowledge will give the close combatant a capability overmatch on the battlefield.

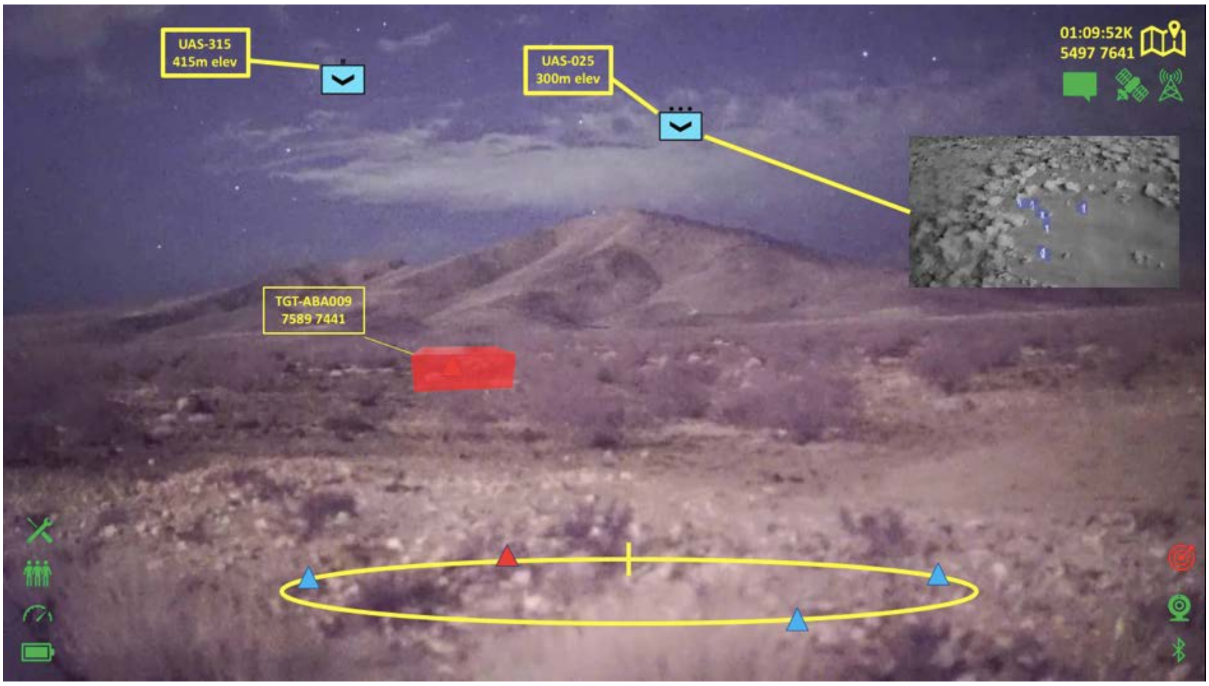

Figure 22. Representative IDHS Augmented View

Today's Technologies

Digital Vision

In current 'analogue' I2 night NVD systems an intensifier tube is used to amplify ambient light. The device converts photons to electrons and multiplies them through a micro channel plate before they are displayed through a phosphor screen. Vision from an analogue tube cannot be recorded, stored or shared unless another device converts it to a digital format.

A thermal imaging (TI) weapon sight is a sighting device combining a compact thermographic camera and an aiming reticle. They can be added as 'clip-on' devices to I2 NVD. TI sights can operate in total darkness. TI sights enable combatants to detect via image the presence of warmth against backgrounds, converting into a digital signal that can be displayed within the sight or recorded, stored and shared in a digital format

A digital NVD (DNVD) converts an optical image into an electrical signal through a Charge-Coupled Device (CCD) image sensor. A CCD sensor has millions of tiny pixels that collect incoming light. The sensor then registers a value for each pixel and converts it into a picture on an LCD screen. This screen can be within the eye piece, in the same fashion as analogue night vision devices. DNVD vision (data) can be recorded, stored, shared and digitally analysed (AI). Sophisticated DNVD already exist for platforms (crew served weapons, vehicles, rotary wing, UAV) but the size and power constraints have limited the use of DNVD for the close combatant. DNVD have also been constrained by quality of image and weight.

This paradigm has now changed and relatively sophisticated DNVD are now becoming available, or under development, that are suitable for the close combatant to use. Unlike analogue I2, DNVD are now capable of producing colour imagery. The transition to digital system can mean reductions in price, weight, length, bulk and power requirements. Digital NVD are not limited by the requirement to incorporate an I2 tube, with the ability to 'flatten' the camera. The electronics that make up the digital NVD are also shrinking dramatically, and this will accelerate with the progress of transistor miniaturisation. DNVD are also becoming available that incorporate and 'fuse' TI data. At 540g for a weapon sight these new sights are capable of replacing all three of the Army's current individual day, I2 and TI sights.

This miniaturisation and flattening also sees the advent of DNVD and fused DNVD/TI for head mounted use. Head mounted DNVD enable vision (data) to be captured from the combatant's POV. The combatant's digital POV can be shared with other combatants and commanders as well as stored and/or transmitted. This POV data can then be processed by AI and become part of 'big data' to be exploited as knowledge with deep neural networks.

Augmented Reality

Digital Vision is an enabler for the introduction of AR for the close combatant. AR is an environment where the objects that reside in the 'real-world' are "augmented" by computer-generated perceptual information. (12) Digital vision derived from DVND, whether head, weapon, vehicle or aircraft (UAV etc) can be superimposed over the combatant or commander's 'real' POV through projecting the digital imagery on the interior of a visor. This vision can be superimposed as the POV, or additional imagery can be added.

Additional imagery can include:

- **Navigation aids.** Such as azimuth, MGRS, altimeter, way points, ranges, resupply locations as icons or images.
- **Blue and Red Force tracking.** The location of known or presumed friendly and enemy force elements. Element status can be conveyed by colour, image, icon or 3D volume. This can include elements of 'certainty' over the veracity of the information.
- **Personal health and usage management system (P-HUMS) information.** This might include the status of the combatant's physiological health (HR, CBT, HRV, VO2 Max, RR etc), ammunition/munitions status, available power on person, communications availability/status etc.
- **Additional shared POV.** The combatant could view the POV of another DVND on his person (weapon) or from another combatant's DNVD, either as his 'whole' POV or as a WIW within his POV.
- **3D Volumetric Displays.** Unlike the imagery and iconography above, the use of 3D volume imagery can enable the assimilation of massively complex data within very rapid periods of time (<150msec), including multiple images concurrently. These complex images can include:
    - o Volumes that represent the real or proposed impact and 'danger safe' areas of applied fires, including close air support (CAS), naval gunfire support (NGS), artillery or missiles.

- o Volumes that represent spaces that the combatant needs to be cognizant of for safety, such as movement boxes within an assault, paths to be kept clear for casualty evacuation aircraft or applied fires in transit.
- o Arcs of fire and danger areas of command detonated munitions, arcs of fire of crew served weapons.
- o Line of Sight (LOS) of enemy observers/sensors/weapons (showing safe or hazardous area distinctions) and 'dead ground' for manoeuvre.

Digital Recognition Technology

The digital imagery gathered by a DNVD can be leveraged to provide data for analysis for digital recognition technology. This can include:

- **Biometric Facial Recognition (BFR).** Vision data collected from the DVND can be processed to derive BFR of any subject within the POV where sufficient clarity of vision will provide 100 pixels across the eyes. (115)
- **Object recognition.** Vision data collected from the DVND can be processed to derive object recognition (camouflage pattern, weapon, vehicle, optical character recognition (OCR)) where sufficient clarity of vision will provide sufficient points of comparison.
- **Gait Correlation Analysis (GCA) Based Human Identification.** Vision data collected from the DVND can be processed to derive GCA of any subject within the POV with sufficient clarity of vision. Human gait identification aims to identify people by a sequence of walking images. Comparing with fingerprint or iris-based identification, the most important advantage of gait identification is that it can be done at a distance. (116)

Gunshot/UAV Detection

The benefits of personal gunshot/UAV detection and location systems are:

- Notification of enemy threat over vehicle noise and other activity.
- Immediate location of a shooter for close combatant orientation for cover.
- Digital input of the (red) data to the BMS (and HUD).
- Deconfliction with known friendly (blue) force locations.

The key benefit of an integrated and digitised gunshot/UAV detection/location/tracking capability is the generation dynamic red (enemy) force location data as they fire and move. This dynamic data can give indications of enemy tactical manoeuvre (advance, withdrawal, delay). Dynamic data can also be analysed with machine learning and smart algorithms (AI) over the wider schema to generate enemy activity mapping and likely movements/intentions. Whilst this may seem routine, up until this point the generation of red force data by close combatants has been via manual input or via text or audio to others. To generate this level of confidence, without risk of 'fat fingers', misreading or mistaken hearing, within a second of the occurrence, is unparalleled. This data is then shared (amongst the team) and distributed (to the higher command and/or IBS) for processing the data for conversion to knowledge for visualisation at all levels.

In the Mouth Transceivers

The development of ITM transceivers has the capacity to significantly improve audio communications as well as enable the introduction of new features. The key benefit of an ITM transceiver is the ability to produce clearly articulated and enunciated speech. As previously outlined, each (current) component of the proposed IDSS is a wonderful technology in and of itself. When combined with other technologies, the effects are amplified. The ITM transceivers are game changers in delivering clear articulation and enunciation on the battlefield, irrespective of ambient noise. In doing so they also enable the introduction of voice recognition software that would otherwise be unable to function within the battlefield due to the exigencies of battlefield noise.

This is capable of enabling the following future capabilities:

- Voice recognition driven applications (app) style pop-up menus for AR within the IDHS ("NAV" = Navigation, "BLUE" = blue force, "STATUS-X" = status of the following system i.e. power, ammunition/munitions, communications etc).
- Voice recognition executed commands for interface controls with semi-autonomous robotic vehicles (UAV, UGV etc).
- Voice recognition driven wireless communications, where the articulated speech is the identification for both the senders and recipients of the communication exchange.

Physiological Data Monitoring/Management

As previously discussed, the development of PDM has the capacity to significantly improve the management of physical health in the field. It also has the capability to significantly enhance the following:

- gauge pre-enlistment baseline fitness;
- guide fitness development;
- provide Workplace Health & Safety tracking and alerts;
- track changes in data over time/against activity;
- provide feedback/guidance to nutrition and diet;
- provide warning of adverse physiological events;
- provide dynamic physiological data reporting;
- assist in physical and psychological recovery methodologies; and
- provide guidance to post-service management.

Within the combat environment, an integrated PDM sub-system can provide the following new capabilities:

- **Immediate and ongoing status notifications of a casualty.** Even when the casualty is unable to communicate, vital data on the medical issue is immediately available to first responders.
- **Data to guide medical response in the field.** This might include direct observation and guidance from a trained medical professional, via the POV of the in situ medical first

responder. The medical professional is also monitoring and assessing the physiological symptoms, combined with the direct POV on the casualty.

- **Intervention and guidance from specialist medical personnel in the field.** Via the PDM reporting and the in situ medical first responder. This might include burns, cardio-thoracic or neuro specialists.
- **Intervention and guidance of specialists within the casualty evacuation process.** Availing of the ability to simultaneously 'see and hear' (vide the first responders digital vision imagery) while viewing vital PDM data.

All data derived from monitoring, both pre-deployment and operational, is then available to the Health Knowledge Management (HKM) system envisaged under Joint Project 2060.

Power and Data Management

Power and data management systems (PDMS) are now available for integration into load carriage systems (LCS). These are offered by a range of providers with varying features and options. The key to successful PDMS is the ability to be agnostic within the framework of the GSA. In this manner, connectivity will be achieved with all interfaced items, providing the balance and focus necessary.

Points to consider in implementing a PDMS may include:

- The ability to provide input to the P-HUMS functionality for the AR in the IDHS.
- The ability to respond to operational requirements defined by the user, such as:
  - Much like a sick patient, the ability to redirect power away from non-essential devices to essential devices in the event that there is insufficient to support all.
  - The ability to automatically switch to alternate power modes (night time, day light/low light, pre-defined inactivity periods combined with bodily orientation).

Power Storage and Provision

As with the PDMS, new technologies are becoming available that will considerably improve power output from batteries, with advances such as Lithium Ion Silica, with figures offering doubling of output by weight and volume on current systems.

This may be combined with opportunities outlined in the PDMS description above, with a move away from individual power supplies on personal systems, NVD, communications, BMS, laser range finders etc) to shared power (by cabling, induction or rechargeable) and harvested power.[5]

The replacement of bespoke batteries (CR123a, Li AA, Li AAA, Harris 152 etc) with a centralised power source or sources, allows for efficiencies in logistics, management and sharing. A proffered harvestable supply (e.g. car battery) may then be shared by multiple end users. The carriage of a portable diesel generator, group battery or similar (think Fokker e-Lighter) (117) could then be passed around the section over the course of the day so that all get a resupply of power.

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[5] Harvested Power. The gathering of power from multiple sources consecutively or concurrently, such as solar power, wind turbines, generators, vehicles, aircraft etc.

Power Harvesting

Following on from the points above, power harvesting is another key attribute. In addition to the description and options above, probably the key interface is that of the close combatant and the vehicle in which he travels.

Alongside the issue of agnostic GSA applications and appliances, the IDSS concept requires agnostic vehicle interfaces. This will enable a generic equipment close combatant (or crewman) to sit in any seat of any military vehicle as an interface. By way of interface the close combatant would then be able to receive power (inductively) and data (closed field WIFI, NFMI or similar) from the vehicles power and data systems. The requirement for inductive charging negates risk of being tethered to the vehicle in the event of an emergency debus event.

The receipt of data within a closed field will enable the combatant to access data from the IBS without the requirement to act as an external node to the vehicle.

Shared vehicle POV

The receipt of data within a closed field will also enable the combatant to access the vehicle sensors (digital cameras), on the externalities of the vehicle, as a POV within their AR view options. They could then sit in the vehicle and observe the outside of the vehicle in any orientation that the vehicle possesses (panoramic?), as if the vehicle hull did not exist, as with the pilot in an F-35.

Similarly, all occupants of the vehicle would have the ability, if allowed, to receive the POV of any of the vehicle's digital weapon sights, remote vehicles or BMS systems.

Shared Vehicle POV

The receipt of data within a closed field will also enable the combatant to access the vehicle sensors (digital cameras), on the externalities of the vehicle, as a POV within their AR view options. They could then sit in the vehicle and observe the outside of the vehicle in any orientation that the vehicle possesses (panoramic?), as if the vehicle hull did not exist, as with the pilot in an F-35 JSF. (118)

With this in mind it is not a great leap to the integration of the IDHS POV into the vehicle (HUD with vehicle HUM-S display for the driver) and the vehicle armaments (HUD for the gunner, with a shared POV for the commander/s).

Common Dismounted/Mounted Soldier Combat Ensemble

Following on from the coverage and thoughts on the UK "Fight Light" discussion earlier in this paper, the requirement to reduce the weight of the close combatant's SCE needs to dovetail into the issue of commonality of mounted/dismounted SCE. In this there is also the requirement to seek balance between cognitive ability, agility, lethality and survivability.

Cognitive ability resides with the reduction in weight of SCE, combined with visualisation methodologies described earlier.

Agility covers a wider range of issues, such as:

- The ability of the combatant to wear the SCE outside the vehicle for long periods without significant detriment to mobility, comfort or health.
- The ability of the combatant to wear the SCE inside the vehicle for long periods without significant detriment to mobility (within the environs of the vehicle), comfort (in his allotted seat, whether mounted or crew) and health.

Without disregarding the issues of lethality and survivability, the issues within agility should be explored further.

Wearing the SCE outside the vehicle for long periods without significant detriment to mobility, comfort or health.

 - Multiple studies have demonstrated that poor SCE design can evidence significantly greater fatigue, resulting in reduced cognitive ability and agility.
 - Exoskeleton designs are struggling to find a balance between utility, power, comfort and agility.
 - Basic exoskeleton configurations (though not necessarily described as such) have been in use for many years in the form of waist belts and straps, either configured with the SCE or the load carriage system or both.
 - These basic exoskeletons (hip belts) seek to remove the weight off the shoulders (and thus spine and lumbar region), transferring it to the hips, where it is more readily borne. (53) Examples such as an "integral 'spine' – the 'dynamic weight distribution' system." (11)
 - These systems not only need to assuage the issues of fatigue induced cognitive loss but also agility, i.e. the combatant needs to be able to fire and move in contact with the enemy. Basic exoskeletons need to allow flexing of the torso whilst still maintaining the support of the weight of the SCE when required, without resorting to frequent 'disconnection" of the exoskeleton.

Wearing the SCE inside the vehicle for long periods without significant detriment to mobility, comfort or health. As with external carriage, studies have demonstrated that poor SCE design can evidence significantly greater fatigue, resulting in reduced cognitive ability and agility, whilst worn in the vehicle.

Mounted combatants are also exposed to whole-body vibration (WBV). Whole-body vibration such as that experienced by vehicle occupants can increase the risk for musculoskeletal injury, in particular the spine. Whole-body vibration exposure experienced by occupational drivers has been shown to lead to muscle fatigue and weakening of the lumbar musculature, resulting in decreased spinal support and increased risk of spinal injury. (51)

Sitting in vehicles with an external load (e.g. SCE) may exacerbate the effects of WBV and the subsequent risk for musculoskeletal injury. Studies showed a trend for decreased height of lumbar vertebra which was statistically significant for the second lumbar vertebra. Furthermore, when sitting in vehicles with an external load (e.g. body armour) is combined with poor seated posture, exposure to WBV may further increase risk of musculoskeletal injury (e.g. lumbar disc failure). (51)

While Rob Orr's study shows there is a lack of research in the military context, his evidence strongly suggests that mounted personnel will likely experience adverse health outcomes as a consequence of WBV exposure. This would tend to reinforce the importance of personal dismounted SCE, and its integration to the vehicle, in performance and injury management of personnel. (51)

Where cross over may be possible is the design of the Crye Precision Adaptive Vest System (AVS)™ and the AVS's Adjustable Structural Kinetic Support System (StKSS)™, (119) combined with Crye's Low Profile Blast Belt™ (120) or Crye's AVS Low Profile Belt™. (121) Whilst already in extensive use with US SOCOM units (122) the Crye AVS with Adjustable StKSS was adopted for use by Australian SOCOMD medical staff as the only system available that mitigated the full extent of back injuries to allow operators to continue in training. The AVS/StKSS/Low Profile Belt combination allows unrestricted forward/backward flexibility, with supported left/right movement, keep the weight of the SCE off the spine/lumbar region, transferring it to the waist.

Where it is believed the AVS™ offers true cross over is in its adaption to the vehicle seat and possible mitigation of the WBV issues. With the belt tightened for dismounted use, the weight resides on the waist, per design. When mounted (seated), the belt can be loosened, enabling the belt to "sit" on the seat around the combatant's hips. It can then be loose enough to be comfortable, yet still retain the ability to support the SCE weight using the seat surface as the base to carry the SCE weight, rather than the waist. When required to debus the vehicle, the AVS™ belt can then be tightened with one hand, and further adjusted when out of the vehicle. For added benefit, the AVS Low Profile Belt™ may provide some additional lumbar support in position behind the combatant. With the StKSS™ on the sides rather than at the back of the SCE/belt, there is not discomfort to the back region. The Combatant also retains full forward leaning agility and left/right is not usually required, given that they are seated side by side in the vehicle.

Figure 23. Crye Precision AVS with StKSS and Low Profile Belt
(Image courtesy of Crye Precision)

Novel Materials Solutions

Following on the theme of the UK "Fight Light" doctrine, the introduction of "novel materials" are also a disruptor to the status quo of equipment. Once such disrupter are graphene antennas. (123) At one (1) atom thick, this printable antenna has excellent propagation properties, with increased gain and range. Capable of multiple wavebands (VHF, UHF, GPS, 4G/LTE and more) the Vorbeck antenna offers reduced weight and a reduced signature, both physical (no antenna pole) and from a signals intelligence (SIGINT) perspective (reduced power for equal or greater range = reduced risk of detection or jamming). This range of wearable electronics is quite broad and other capabilities include sensors and flexible electronics.

Another novel material is the use of Bi-stable Reeled Composite (BRC). (124) This is a tough fibreglass type material that is manufactured to have two modalities. In the first, the material rolls up like a tape measure, forming a compact roll. On rolling however, the material reforms into a tube, like an almost closed letter C, giving the tube sufficient rigidity to maintain itself as pole/tube to a height of at least 10m. The material can also be manufactured with various antenna embedded in the material skin, to create multi-waveband antenna. Other uses include tripods and camouflage net poles. (125)

Complex ballistic shapes are also now becoming possible on an individual level at acceptable prices. Composite Consolidation Technologies (CCT) were initially developed as a batch-type manufacturing process for ballistic protection laminates, specifically Small Arms Protective Inserts (SAPI). CCT employs programmable cycling of significant isostatic pressure (>100bar) and temperature to achieve composite consolidation in thermoset and thermoplastic based systems. Significant isostatic pressure is applied to the article being manufactured within the processing chamber by a circulating liquid medium that transfers heat extremely efficiently. CCT is applicable to a wide range of lightweight armour and has the ability to form large and small complex shapes. (126)

Researchers at the University of Maryland in the US have developed a new fabric that reacts to body temperature and humidity levels to ensure the wearer is never too hot or too cold. Made from specially engineered yarn, the fabric was created with fibres made from two different synthetic materials, one that absorbs water and one that repels it. The fibres are coated with carbon nanotubes, and they each expand, or contract, based on temperature changes. When the material gets hot and wet, in response to sweating, the strands tighten up, activating the nanotube coating. Like the body's pores, the fabric lets the heat pass through. When the body is too cold, the mechanism is reversed and closes up, trapping body heat. The fabric can be knitted, dyed, and washed like any other fabric, so it offers a lot of design freedom. (127)

Human-Machine Teaming

Robotic warfare is fast becoming a reality. (12) The introduction of semi-autonomous (human in the loop), supervised autonomous (human on the loop) and fully autonomous (human out of the loop) weapons of war (whether armed or unarmed) has been the military's major drive, alongside and hand in glove with, AI.[6] There is also little doubt that adopting a closer

[6] Loop in this context refers to the OODA loop (observe, orient, decide, act, REPEAT)

integration of humans and machines offers significant potential advantages to military organisations. (128)

Whilst the higher level of discussion re the opportunities and threats, advantages and disadvantages of the introduction of robotic warfare is beyond the scope of this tactical level discussion, the issue of human machine teaming is. Significant tactical and operational advantage can be gained through human-machine teaming. Semi-autonomous machines already exist at the tactical level, with the introduction of the FLIR PD-100 Black Hornet micro UAV. (129) The PD-100 is semi-autonomous insofar that it can follow a pre-determined path, return to hover and self-orient, with a human in the loop. This is currently undertaken from a ruggedized control pad (similar to a table computer) operated by a close combatant. Only the operator can direct the PD-100 or view the imagery.

Discussions with the Original Equipment Manufacturer (OEM), FLIR of Norway, (130) indicates a path forward with the PD-100 imagery able to be taken as a POV or WIW within an AR visor like the IDHS. In this manner, the operator (or anyone else given the access to view the POV and/or manoeuvre the device) can fly the PD-100 with the PD-100 POV shared with multiple users. Flown forward to identify a target, the operator can then alert a commander to a possible target for confirmation/decision on engagement.

If necessary, the PD-100 control could be handed over or shared with a supporting fires coordinator, such as a Joint Terminal Attack Controller (JTAC) for prosecution (distributed and recorded for later analysis). Following prosecution, the JTAC could record and analysis the target area for battle damage assessment (BDA) prior to handing back control of the device. Inherent within the above scenario is the use of AI for processing visual data collected by the UAV. The same use can be made of armed UAV/UGV on the battlefield, with a mix of semi-autonomous, supervised autonomous and fully autonomous systems employing the IDHS HUD POV/WIW concept for supervision/intervention.

Immersive Simulation

Immersive simulation has now been around for over a decade in the civilian and military environments. This includes both AR and VR (virtual reality). Where the IDHS with AR HUD brings this forth into a true immersive simulation paradigm is the ability, with the AR HUD, to completely encapsulate the experience of the combatant with simulated contexts, whilst in a field environment. Virtual enemy figures, smoke, flame, buildings, munitions and vehicles can be augmented into the physical training environment, with the combatant responding to and engaging with, these virtual figures.

This encapsulation can take place in all the modalities within the combatant's environment, including dismounted, mounted, crew, combat support and combat service support roles. This has the capability to significantly enhance realism in training, reduce costs and provide comprehensive feedback for improvements in technique. Combatants can undertake mission rehearsal and pre-deployment preparation within a near identical environment, inclusive of correctly attired, armed and responsive enemy combatants, non-combatants and civilians. Rules of Engagement (ROE) can be rehearsed through multiple contexts with guidance.

This is not to say that immersive simulation activities would be rigid. The ability of cloud computing and deep learning could create an adaptive and self-aware adversary. These lessons could then be learnt prior to lethal exposure to the actual adversary and counters developed.

Tactical Signature Management

With the advent of even more sophisticated UAV systems, signature management at the individual and small team/vehicle level will mean the difference between success and inhalation on the modern battlefield. Australia and its Allies aren't the only ones with UAV fitted with multi-spectral sensors and AI for crunching big data for "pattern of life" analysis and targeting.

If proper cognizance of this threat is taken, this will significantly change the behaviour of all combatants on the contested battlefield in any peer or near peer conflict. The intent of any combatant will always be to act as an exemplary uncooperative target. Examples will include but not be limited to:

- **Manoeuvre.** Any type of manoeuvre or individual movement will become an activity not undertaken lightly. It will involve constant assessment of threat, scanning of the environment and constant SA. Maximum masking of signature, distractions, and minimalization of movement will become the norm. It may be that future tactical and operational manoeuvre is always be difficult due to the threat posed by precise long-range weapons, the unblinking eye of sensors and aerial killing machines that guarantee the unshielded manoeuvre will be nearly as suicidal. (12)
- **Emissions.** Emissions of any type, whether visible (cooking, lighting, signalling, smoke, flares), invisible (weapon lasers, target designators, non-A2/AD compliant communications) (12) will draw attention and responses. Use should be made, where possible, of Low Probability of Intercept/Low Probability of Detection (LPI/LPD) communications. (17) (16)
- **Repetition.** With the use of sophisticated sensors scouring the environment, combined with deep neural learning, any repetition may result in predictive analysis of one's likely intent and next movement, even if otherwise concealed. Repetition will draw attention and attention will draw a response. Much like walking with a steady gait on the sands of the planet Arrakis will draw the SandWorm's wrath (131) (132), so too will repetition draw fire/s.
- **Anonymity.** Deep neural networking tool sets, with the ability to recognise human faces, are freely available on the internet. (133) These pre-configured data sets, though configured for other features, can have the top layers stripped off and retrained to recognise human features. These packages then be run using a Raspberry Pi credit card sized processor (12) on a drone brought from any electronics store for less than $1,000. Expand that now to even a remotely near peer adversary? Recognition characteristics can include faces, weapons, camouflage patterns, insignia etc.

The Australian Army will always need to train as it will fight, therefore able to fight as it trains. Drills need to be taught in training and adhered to in all circumstances, even if it expensive, inconvenient or time consuming. Similar to the sentiments outlined in the US Joint Operating Environment 2035 (JOE2035) Army must "simultaneously adapt and evolve while neither discounting nor wishing away the future reality of strife, conflict, and war." (134) (10)

Remote Fires

As a sensor and a node, but also as a target of enemy sensing, the close combatant should seek to minimise his own role as a lethal component in the close combat team and instead become the node for remote fires whenever and wherever possible. Making best possible use of the multitude of fires available from Joint and Combined assets will create both a "cone of impunity" (7) and provide the lethality needed to defeat the adversary. The intent being not to expose the tactical unit to enemy awareness and fires, but to stand back and use one's own fires instead.

These will consist of remote fires in the shape of artillery and mortars, semi-autonomous kinetic UAV/UGV, loitering munitions, command detonated munitions etc. Acquisitions under Project Land 4108 identifies loitering munitions and unmanned weapons systems amongst the systems to be acquired by Army. The 2016 Defence White Paper advised that Army will acquire a new long-range rocket system in the mid-2020s to complement Army's existing artillery capability. (10) The new system will be capable of providing fire support to defeat threats at ranges of up to 300km.

Available RAAF guided munitions, launched from F/A-18s and F-35 include the AGM-88 HARM Anti-Radiation Missile, AGM-154 Joint Standoff Weapon (JSW), AGM-158 Joint Air-to-Surface Standoff Missile (JASSM) and Joint Direct Attack Munition (JDAM). (8) RAAF will also acquire 12-16 armed General Atomics MQ-9 Reaper, though the nature of the armaments is still to be determined. (9)

The Integrated Digital Soldier and Disaggregated Combat for the 21st Century

The Australian Context

The Australian soldier in the first two decades of the 21st Century is still fighting much as he did at the end of the 20th Century. Whilst the cost of the equipment has soared ($3700 in 1999 to $27,700 in 2013, and rising), (27) the equipment has also improved substantially in quality, and technology is more widely distributed. (29) Notwithstanding these improvements, many of the technologies remain analogue, (25) unable to assist the close combatant's integration into the whole. SA outside of the immediate environs is limited, and signature protection is based on awareness and technologies that are dated in comparison to peer/near peer sensor capabilities. (135)

In the sensor saturated 21st Century battlefield (134) the advent of KCW (sometimes known as 5th Generation Warfare) will substantially change the way that the tactical element, whether Section, Platoon, Combat Team or Battlegroup, manoeuvres and fights. Knowledge and SA (1) will win the battle, keeping ahead of the adversary's OODA loop.

To utilise the vast amount of knowledge that is, and will continue increasingly to be, (47) (48) generated on the battlefield, (4) (111) knowledge and SA need to be rapidly assimilated. This data will need to be gathered, stored, synchronized and distributed to ensure that the maximise knowledge is gathered and re-distributed as possible. Incorporating deep neural computing to establish patterns and links within adversary actions.

Conversely, staying alive and effective will become increasingly more difficult. (7) The advent of deep neural computing and AI will drive fundamental changes to warfighting. (116) Pattern of life sensing, (18) facial recognition, (115) gait correlation analysis (116) will likely defeat the 5SM drills (shape, shine, silhouette, shadow, spacing and movement). The application of comprehensive and rapid fires by the adversary on to any suspected or predicted Australian force element is to be anticipated.

The Integrated Digital Soldier

The purpose and utility of small force elements on a contested peer/near peer battlefield will no longer be simply to win the close fight. (49) A small force element engaged so decisively that it has no alternative, but close combat, might be considered to have failed. (7) This may be considered to distract them from their role as human nodes and sensors. (7) Should they, much like Special Forces elements, become more sensors and facilitators for remote fires, at arm's length from the enemy, using artillery, CAS or long range rockets. (10)

To manoeuvre tactically to remain a sensor and a node on the battlefield, the close combatant must have exceptional SA and agility, with lethality and protection secondary. SA will come from the close combatant will utilising knowledge derived from multiple support systems previously reserved for higher echelons. This must be presented visually in 3D natural forms to allow for assimilation at the rate in which it can be distributed, whilst still allowing the close combatant to be factually engaged with his immediate environment.

Agility will be derived by stripping the combatant of all unnecessary "just in case" ancillaries and prioritising weight, bulk and multiple utility over robustness or cost. "Just in case" must be replaced by “just in time” except for the absolute minimum. Lessons must be taken from the outdoor industry who have refined the paradigm of austerity in load to a fine art. Compressible clothing, 3D printed equipment items, minimalistic construction and the latest material technology must be inculcated as opposed to meeting minimum specification and the lowest tendered price. Graphene antenna are simply an example of leveraging technology already available. The civilian market already utilises “drone” deliveries for “just in time” commodities. Adapting these methodologies (not necessarily technologies) will also drive agility.

Lethality needs to be revisited. Exposure beyond sensor range is exposure to enemy sensors and unnecessary in a contested environment where remote fires can be employed. Wherever possible lethality must be applied from remote capabilities. This will not only allow for greater lethality from more sophisticated capabilities but also alleviate the requirement to carry excess munitions on the close combatant.

Protection must be afforded to the greatest threat, detection. Signature management and SA will be the keys to protection. Being difficult to find will make the close combatant safer than the ability to negate the kinetic result of being detected in the open.

Summary

The Australian Army must simultaneously adapt and evolve while neither discounting nor wishing away the future reality of strife, conflict, and war. (7) Warfare against a peer or near peer threat will be characterised by the use of autonomous or semi-autonomous weapons systems in the air or on the ground. (12) (48) These weapons systems will use sophisticated sensors to detect any signature, across all spectrums (112) (75) (13) (15) Army must also creatively account for the unexpected by stepping outside the assumptions and certainties that anchor training and operations to yesterday’s war. (7) Manoeuvre, emissions, repetition and anonymity are shields that assist SA, agility, lethality and protection.

For success in this arena, SA is the key overriding issue. In combat, irrespective of any other attribute of the combatant, SA is the most important attribute keeping the combatant alive and effective. (1) When the combatant has superior SA to an adversary, this allows the combatant to dictate the terms on which the battle is fought, whether at the tactical, operational or strategic level. (2) SA is afforded by knowledge, which must be assimilated. (3) The combatant who assimilates the essential knowledge fastest achieves superior SA. (1)

Added to this is the inclusion of adaptive uncertainty visualization, which significantly reduces a user’s cognitive load in an environment where both stress and uncertainty abound. (24). This has clear implications for military situations where combatants are subject to high cognitive load.

SA as the key driver to success in modern combatant, assimilation of knowledge is the key driver to SA. Assimilation of knowledge on the battlefield can be accomplished faster and more comprehensively with visualisation of knowledge. (21) (3) For visualisation of knowledge to be most effective, it is best presented as 3D volumetric natural shapes, supported by colours (22) (23) and representation of uncertainty in that knowledge to support decision making. (24)

Abbreviations and Acronyms

Abbreviation	Meaning
2D	Two Dimensional
3D	Three Dimensional
5SM	Shape, Shine, Silhouette, Shadow, Spacing and Movement
A2/AD	Anti-Access/Area Denial
ABI	Activity Based Intelligence
ADF	Australian Defence Force
AI	Artificial Intelligence
ANAO	Australian National Audit Office
AR	Augmented Reality
ASSA	Australian Soldier Systems Architecture
AVS	Adaptive Vest System
BDA	Battle Damage Assessment
BFR	Biometric Facial Recognition
BMS	Battle Management System
BMS-D	Battle Management System – Dismounted
BMS-M	Battle Management System – Mounted
BNVD	Binocular Night Vision Device
BRC	Bi-stable Reeled Composite
BRIG	Brigadier
C2	Command and Control
C3I	Command, Control, Communications and Intelligence
CAS	Close Air Support
CBRND	Counter Biological Radiological Nuclear Defence
CBT	Core Body Temperature
CCD	Charge-Coupled Device
CCT	Composite Consolidation Technologies
CED	Cooperative Engagement Capability
COIN	Counter Insurgency
CONOPS	Concept of Operations
COP	Common Operating Picture
CP	Colour Perception

Abbreviation	Meaning
CTTSO	Combating Terrorism Technical Support Office
DDG	Guided Missile Destroyer
DGFLW	Director General Future Land Warfare
DNVD	Digital Night Vision Device
DSTG	Defence Science and Technical Group
DSTL	Defence Science and Technology Laboratory (UK)
DSTO	Defence Science and Technology Organisation
EA	Electronic Attack
EEG	Electroencephalography
EW	Electronic Warfare
FEBA	Forward Edge of the Battle Area
FFG	Guided Missile Frigate
FUP	Forming Up Place
FY	Financial Year
g	Gram
GB	Gigabytes
GCA	Gait Correlation Analysis
GPS	Global Positioning System
GSA	Generic Soldier Architecture
GVA	Generic Vehicle Architecture
HCI	human- computer interaction
HKM	Health Knowledge Management
HQ	Headquarters
HR	Heart Rate
HRV	Heart Rate Variability
HUD	Heads Up Display
HUD	Heads Up Display
I2	Image Intensification
IAMD	Integrated Air Missile Defence
IBS	Integrated Broadcast System
ICW	Information Centric Warfare
IDHS	Integrated Digital Helmet System

Abbreviation	Meaning
IDSS	Integrated Digital Soldier System
IFC	Integrated Fire Control
IOC	Initial Operating Capability
IP	Internet Protocol
ISREW	Intelligence, Surveillance, Reconnaissance, Electronic Warfare
ITM	In the Mouth
JASSM	Joint Air-to-Surface Standoff Missile
JDAM	Joint Direct Attack Munition
JOE	Joint Operations Environment (US)
JSF	Joint Strike Fighter
JSW	Joint Standoff Weapon
JTAC	Joint Terminal Attack Controller
JTT	Joint Tactical Terminal
KCW	Knowledge Centric Warfare
Km	kilometres
LCD	Liquid Crystal Diode
LCS	Load Carriage System
LD	Line of Departure
LED	Light Emitting Diode
LNIC	Land Network Integration Centre
LOS	Line of Sight
LPI/LPD	Low Probability of Intercept/Low Probability of Detection
MANET	Mobile Ad Hoc Networking
MGRS	Military Grid Reference System
MOD	Ministry of Defence
Msecs	Milliseconds
NFMI	Near Field Magnetic Induction
NGS	Naval Gunfire Support
NIR	Near Infrared
NVD	Night Vision Device
OCR	Optical Character Recognition
OEM	Original Equipment Manufacturer

Abbreviation	Meaning
OODA	Observe, orient, decide, act
P-HUMS	Personal Health and Usage Management System
PCW	Platform Centric Warfare
PDM	Physiological Data Monitoring
PDMS	Power and Data Management System
PED	Processing, Exploitation and Dissemination
PEO	Program Executive Officer
PET	Polyethylene Terephthalate
POC	Proof of Concept
POL	Pattern of Life
POV	Point of View
PP	Polypropylene
PRC	Peoples Republic of China
PRC	Peoples Republic of China
RAAF	Royal Australian Air Force
RADAR	RAdio Detection And Ranging
RAN	Royal Australian Navy
RMA	Revolution in Military Affairs
ROE	Rules of Engagement
RR	Respiration Rate
SA	Situational Awareness
SAPI	Small Arms Protective Inserts
SCE	Soldier Combat Ensemble
SIGINT	Signals Intelligence
SINGCARS	Single Channel Ground and Airborne Radio System
SM	Signature Management
SOCOM	Special Operations Command (US)
SOCOMD	Special Operations Command (Australian)
SPR	Soldier Personal Radio
StKSS	Structural Kinetic Support System
SWIR	Short Wave Infrared
TBAS	Tiered Body Armour System

Abbreviation	Meaning
TI	Thermal Imaging
TIE	Tactical Information Exchange
TIR	Thermal Infrared
TTNT	Tactical Targeting Network Technology
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UHF	Ultra High Frequency
UK	United Kingdom
ULCANS	Ultra Lightweight Camouflage Net System
US	United States
UV	Ultra Violet
VHF	Very High Frequency
VIS	Visible (spectrum)
VO2 Max	Blood to Oxygen Mix
VR	Virtual Reality
WAAS	Wide Area Airborne Surveillance
WBGT	Wet Bulb Glove Temperature
WBV	Whole Body Vibration
WIW	Window in Window

Definitions:

Word/Phrase	Definition
Augmented Reality	A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view
Big Data	Extremely large data sets that may be analysed computationally to reveal patterns, trends, and associations, especially relating to human behaviour and interactions
Cloud Computing	The practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer
Cooperative Target	A cooperative target is one that is positively signalling (emitting) such as a RADAR
Deep Learning	An artificial intelligence function that imitates the workings of the human brain in processing data and creating patterns for use in decision making
Exoskeleton	A rigid external covering for the body providing both support and protection
Harvested Power	The gathering of power from multiple sources consecutively or concurrently, such as solar power, wind turbines, generators, vehicles, aircraft etc
Internet Protocol	The method or protocol by which data is divided into a number of packets and sent from one computer to another on the Internet. Each packet can, if necessary, be sent by a different route across the Internet
Laminate	A tough material that is made by sticking together two or more layers of a particular substance
Meshed Network	A computer network in which each computer or processor is connected to a number of others, especially so as to form a multidimensional lattice.
Near Field Magnetic Induction	A short range wireless physical layer that communicates by coupling a tight, low-power, non-propagating magnetic field between devices
Node	A point in a network or diagram at which lines or pathways intersect or branch.
Signals Intelligence	Information gained by the collection and analysis of the electronic signals and communications of a given target
UAV/UGV	An unmanned aerial vehicle, or unmanned ground vehicle, also known as a ‘drone’ is a type of aircraft or vehicle, that operates without a human onboard.

Word/Phrase	Definition
Virtual Reality	The computer-generated simulation of a 3D image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors

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