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The Possible Effects of Potential Key Technological Developments on the Force Structure of the Australian Army in 2040

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ABSTRACT

This report provides the outcomes from a study which provided input to the Australian Army submission for the 2009 white paper. It is a formal documentation of the outcomes and a record of the content which was provided the client in 2008. To understand the potential key technological developments that are likely to impact on the Army After Next 2020-2040, an analysis of future technologies on Army functions was undertaken focussing on impacts to force structures. A modified TOWS (Threats, Opportunities, Weaknesses & Strengths) technique was applied to eleven Army functions across each technology area. Brief assessments are made to the possible impact of future technologies on a range of Army unit types.

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Executive Summary

This study resulted from an urgent Army request to "undertake an assessment of the potential key technological developments that are likely to impact on the Army After Next 2020 – 2040", in 2008[1]. It was required within an 8 week timeframe and was resourced with limited staff. Its goal was to gain a broad look at any possible major impacts to future force structures of future technologies. It was not designed or resourced to be an exhaustive in depth and detailed technology assessment. At the time, the client was provided with the outcomes of the study and this report provides a formal record of the content and outcomes of the study. To allow for interactions between technologies but still maintain the tractability of the problem we consider technologies within the framework of eleven core functions: seven related to joint land warfare and four from the other elements of Adaptive Campaigning. Within each area, the TOWS (Threats, Opportunities, Weaknesses & Strengths) technique is used to highlight the possible impacts to the force structures brought by the possible key technological developments. An assessment is made of the possible resulting impact to a range of Army unit types though this is brief and not exhaustive. The initial analysis identified no unit type which would be rendered redundant in the 2020 to 2040 timeframe. In general the introduction and uptake of some of the new emerging technologies may result in the Australian Defence Force (ADF) being able to do more with less and the counter to that position is the potential deskilling of personnel able to undertake tasks when the technology fails or is not available. The greatest gaps in capability and structure appear to be likely in the four Adaptive Campaigning functions additional to the joint land warfare functions and with the introduction of additional capabilities and concepts particularly in this area in addition to the ADF's traditional military roles. A robust future force structure also needs to:

- Unify forward calls for fire from all joint indirect fire assets.
- Be prepared to continue to fight for information as opponents will still be able to drop below the detection threshold even with improvements to detection technologies.
- Support infantry with vehicle mounted assets capable of penetrating armour that overmatches the capacity of any organic infantry weapon and electronic warfare and active defence assets to defeat inexpensive but capable robotic vehicles.
- Prepare for a massive increase in the logistical requirements of deployed forces.
- Take advantage of the ability of the potential ability of a single operator to remotely control many logistics vehicles or several semi-autonomous robotic fighting vehicles.

[1] Some of the original outcomes from the work have been updated to reflect major advancements/obstacles through to late 2010.

- Continue to distribute decision making and ensure small units remain able to operate independently, augmented by the network but not dependent on it, following the intent of their commanders rather than micromanaged. This means the future deployable force structure needs to use a small enough fraction of the total force to provide appropriate training opportunities.

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Glossary

APS	Active Protection Systems
ADF	Australian Defence Force
BOS	Battlefield Operating System
C2	Command & Control
CSS	Combat Service Support
DSTO	Defence Science and Technology Organisation
IED	Improvised Explosive Device
IFF	Identify, Friend or Foe
IT	Information Technology
MP	Military Police
TOWS	Threats, Opportunities, Weakness & Strengths (analytical technique)
US	United States

1. Introduction

This study resulted from an urgent Army request to "undertake an assessment of the potential key technological developments that are likely to impact on the Army After Next 2020 – 2040", in 2008[2]. It was required within an 8 week timeframe and was resourced with limited staff. Its goal was to gain a broad look at any possible major impacts to future force structures of future technologies. It was not designed or resourced to be an exhaustive in depth and detailed technology assessment. The client was provided a draft copy of the outcomes of the study at the conclusion of the study in 2008. This report provides a formal recorded documentation of the study outcomes.

Predicting the effects of technology on force structures decades into the future is a difficult task. Imagine, for example, the likelihood of success for a futurist asked in 1913 to predict the effects of technology on the force structures of an army in 1945. In the interim the power of rail transport of reserves and supplies, modern artillery, field fortifications and automatic weapons were convincingly demonstrated; the concepts of armoured, aerial and airborne warfare were born and matured and road transport advanced massively. By 1945 airborne and tank formations were present in the force structure as were anti-aircraft and anti-tank units. Technologies did not just lead to the addition of new units to the force structure but they also contributed to the modification of existing elements of the force structure. For example, the scouting role of the cavalry was partly taken over by aircraft but the manner in which they carried out the rest of this role, and the force structures they used, were changed substantially by mechanisation and the introduction of radio. Another example is the veterinary corps that shrank and changed role from dealing with cavalry horses and transport animals (horses and mules) to dog care as mechanisation of transport occurred.

Apart from the individual technologies being difficult to predict (as well as their possible impact on force structures), the interactions between these technologies are also important and are even harder to identify. For these reasons, we do not seek to predict the exact technologies that will impact on force structure in 2040. Rather, we seek to provide a framework of possibilities in eleven functions in an attempt to minimise the regret experienced by the Australian Army in 2040 when they look back at their actions based on the assessments of 2008.

The eleven areas under which we consider potential key technological developments come from a consideration of the skills needed to achieve the desired outcomes in missions given to the Australian Army. Research undertaken over a number of years and across projects at the Defence Science & Technology Organisation (DSTO) determined what the core functions of the Australian Army were (in order to undertake joint land combat) [1, 2]. These core functions were considered to be: engagement; information collection; sustainment; communication; protection; movement and decision making [1, 2]. While the ability to carry out joint land combat is a uniquely military role which differentiates armed

[2] Some of the original outcomes from the work have been updated to reflect major advancements/obstacles through to late 2010.

forces from, say, police; armies need competencies in a broader set of skills to achieve the desired outcomes in the missions that they are set. For this reason we also consider four further sets of functions to achieve the desired outcomes in the missions they are set: population support; indigenous capacity building; population protection and public information [3, 4]. It is important to note that these are at a different level to the other seven functions and hence their analyses are also at a different level. These two sets of existing core functions for the Australian Army provided the authors an immediate framework for considering the effect of the vast array of technology areas on the force structures related to these functions, given the time available.

This document is structured in the following way. The methodology is presented first, followed by the results of its application to the eleven core function areas to identify the plausible range of effects on force structure from potential key technological developments. Following this, a brief assessment is made on the possible impact to a range of Army unit types. Finally, there are some comments on the ethical considerations that need to be made with respect to the uptake and implementation of future technologies as well as the possible gaps which may exist for the Army. Specific detailed areas of interest arising from each of the function impact analyses are presented in Appendix A.

This work is not intended to stand alone but represents an important perspective alongside more predictive work charting the force structure impacts of likely developments in existing technology and likely patterns of technological uptake.

2. Methodology

In order to assess the effects on the future Australian Army of potential technological developments we need a formalisation of competencies it is to be able to perform. These can be found in the functional skills required for Adaptive Campaigning: joint land combat; population support; indigenous capacity building; population protection and public information [3]. Joint land combat is the element of Adaptive Campaigning that is exclusively military and, therefore, further detail is particularly useful in this area. We use a pre-existing taxonomy of skills [1, 2] to break joint land warfare down into seven core functions: engagement; information collection; sustainment; communication; protection; movement and decision making. This gave an overall taxonomy of eleven generic functions for the Australian Army which includes a whole range of competencies necessary for mission success. This pre-existing taxonomy was used as opposed to others specific for the Australian Army [5] as it was the most recent and generic taxonomy available. This taxonomy of functions differed to the one by Ayling[3] and presently used in the development of Australian future warfare concepts, in that the areas were more generic and better suited to being used as a framework for this technology assessment. Certainly the outcomes could be mapped readily into the previous terms.

[3] The functions published by Ayling and used in the development of Australian future warfare concepts are: command, control, computers and communications; intelligence, surveillance and reconnaissance; tailored effects; force projection; force protection; and force sustainment 5. Ayling, S.H., *Future Warfare Concepts: Designing the Future Defence Force*. The Australian Defence Force Journal, 2000(144): p. 5--11.

To determine the technologies of interest, the literature and databases on future technologies was sourced for pre-existing taxonomies [6] which could be used to provide a set of technology areas which could then be applied to the Army functions and assessed in greater detail. Each technology area was assessed against each function area and the assessment was undertaken using a modified form of the TOWS (Threats, Opportunities, Weaknesses and Strengths) technique [7], described below. In each of these eleven core functions we use the modified form of TOWS analysis to identify potential key technological developments and deduce from these the range of likely effects on the structure of the future land force.

The TOWS technique [7, 8] compares external Threats and Opportunities to the internal Weaknesses and Strengths of an organisation to arrive at a set of actions to protect it against threats and allow it to take advantage of opportunities. TOWS is specifically designed to deduce actions and strategies from the matrix thus allowing for useful outcomes of the analysis often not found with the more commonly used SWOT (same acronym as TOWS in reverse) method [7]. The problem of many trivial (and occasionally tendentious) items appearing in the TOWS dimensions can only be dealt with by insisting on justification of items and focusing on the key TOWS through careful consideration of candidate items and vigorous culling of this set before arriving at a terse group of final items.

TOWS is a general framework [7, 8] and typically external Threats and Opportunities are seen as arising from factors related to society, politics, economics, technology, products, demography, markets, competition and etcetera. However, we seek an assessment of how potential key technology developments are likely to alter the force structures of the Army After Next in the 2020 to 2040 timeframe. Therefore we concentrate on technology Threats and Opportunities likely to affect force structure. Our modification to the process couples the technology threats/opportunities to the external influence and the Army structure to the internal weakness and strength. This study was focussed on the impacts of future technologies on force structures. That is why a modified TOWS approach was selected over the commonly used SWOT technique focus as we were interested in the external application and impact effect of the technologies on the force structures – first and then the internal capability secondarily. Table 1 shows an example of the practical application of the TOWS method for analysis in this study.

Table 1 This example TOWS table shows how the TOWS method is applied to each core function and impact technology. Each impact technology area is applied to each function separately.

Army Function: Impact Technology:	Threats (technological) T_1 T_2 T_3 …	Opportunities (technological) O_1 O_2 O_3 …
Weaknesses (structure) W_1 W_2 W_3 …	T_1, T_2, W_3 combined outcome / strategy… T_1, W_2, combined outcome / strategy… T_3 outcome strategy …	…
Strength (structure) S_1 S_2 S_3 …	…	…

When this analysis is undertaken it is possible to put together multiple items from pairs of dimensions to take into account some of the complexity of the situation. While this does not explicitly allow for extremely complex interactions between items from three or four dimensions some of this is captured implicitly because of the complementarity of many item pairs within the TO dimensions and within the WS dimensions. The interactions between potential key technological developments are only considered in light of their likely effect on the force structure of the future Australian Army.

The area of future technology assessment is a rapidly expanding field and one which many governments, corporations and nations now consider to be important enough to incorporate into their strategic planning [9-12]. It is however, a very grey area as the further out in time these technologies are considered, the greater the uncertainty on development, breakthroughs required, potential interactions and societal uptake. However, using previously conducted studies [2, 6, 13], an analysis and grouping of broad technological areas of potential impact were generated which may impact on the Army force structure through to 2040 if they are realised.

3. Modified TOWS of Core Functions

There will be differences in the relative importance of various core functions depending on the exact situation faced by future land forces. To minimise the regret experienced by Australian joint land forces in 2040 a force structure must provide robustness against stabilisation operations in a failed or failing state (where the non-joint land warfare functions from Adaptive Campaigning will be relatively more important); through to combat (possibly in a coalition) against an advanced opponent (or coalition of opponents) with parity in skills and technology; as well as other situations within the spectrum of operations. An appreciation of how potential key technological threats, opportunities, strengths and weaknesses may impact on the future force structure is an important component in developing a robust structure that enables forces to minimise their future regret.

3.1 Engagement

To successfully engage the enemy the joint land force needs to be able to deliver sufficient, appropriate and targeted firepower to prevent their ability to operate. The broad emerging technologies assessed as likely to provide threats and opportunities for engagement between 2020 and 2040 were classed as:

- Automation and robotics;
- Human factors and integration;
- Biotechnology;
- Electronic and information warfare;
- Precision and direct weaponry; and
- Space systems [2, 6, 11, 12, 14].

The strengths for engagement were identified by the previous DSTO study on generic Army functions [1, 2] as being able to position forces well (to engage on favourable terms), having excellent targeting (to be able to hit what you aim at and being able to hit the right target) and having highly capable weapons (to be able to destroy what you hit). The weaknesses were identified as being low enemy vulnerability (inability to hit or destroy the enemy), highly capable enemy weapons (so they can hit and destroy you easily) and positional impotence (lack of control of the terms of engagement) [1, 2].

The key outcomes from the TOWS analysis for engagement were:

- It is plausible that automated driving assist will enable soldiers to concentrate on the enemy rather than on the basics of driving thus allowing a reduction in vehicle crews in future vehicles. The force structure effect is that smaller crews may be as capable in the future as larger ones are now.
- Ammunition and target acquisition technology may make large calibre auto cannons on regular combat vehicles effective as dual purpose anti-light-armour and close range anti-aircraft weapons. This may compress some of the roles of air defence units into mechanised infantry units.
- Sensor, integration and remote sensing technologies may push the discrimination threshold lower and make indirect fire precision weaponry more important in force structures but they will not push the discrimination threshold to zero and there will still be a need to fight for information.
- Autonomous robots are unlikely to be acceptable options for Australia but force structures may need to be modified to cope with opponents using static variants as area denial weapons or mobile ones as terror weapons.
- Semi-autonomous robotic fighting vehicles are a plausible part of force structures in the 2040 timeframe. These may greatly enhance the presence, footprint and firepower of individual operators while adding significantly to the logistics needs of the force.

3.2 Information Collection

The information collection core function covers the process of finding and acquiring useful information about the operating environment [15]. The broad emerging technologies likely to provide threats and opportunities for information collection between 2020 and 2040 were assessed as:

- Electronic and information warfare and the hardware;
- Software;
- Security;
- Communications and
- Sensor aspects of Information Technology (IT) [2, 6, 11, 12, 14].

The important WS dimension items identified in the previous DSTO study [1, 2] were use of the information pool, spectrum covered by surveillance systems, quality of surveillance targeting and volume covered per unit time per sensor.

The key outcomes of the TOWS analysis were:

- Future force structures need to be based around a *continuing need to fight for information*. There will be improvements in information collection technologies but there will always be a discrimination threshold and other technological advances in signature suppression are likely to enable opponents to push their signature lower at the same time as detection abilities improve.
- There is a danger of a loss of human skills in collection that becomes evident when the network connection is not available. A robust future force structure would be built to take advantage of the information collection opportunities of networking whilst not becoming reliant on the networking for individual unit functionality.
- It is important not to lose sight of the fact that the observations and interactions of soldiers on the battlefield will remain the most important source of information available to future commanders. While automated text-to-text translation may be quite advanced by 2040 it seems less plausible that automated speech-to-speech translation will be, so there will be a continuing reliance on the language skills of people in the gathering of information.

3.3 Sustainment

Successful sustainment allows maintenance of operational momentum through the dynamic use of appropriate assets to distribute resources, provide soldier care and maintain capability assets sufficiently to satisfy operational requirements. The controversial part of this definition is the provision of soldier care (including medical, psychological and religious care). This is not included in some dimensionalisations of joint land warfare [15] but is an important factor in the force being able to achieve its goals now and achieve them again in the future. A well functioning future force structure will need to be able to look after its own soldiers as well as looking after its equipment and distributing resources. We consider sustainment to be the most appropriate of the seven core functions to include soldier care under both because it improves the time a force can be sustained in the field and because sustainment shares many features with the present Australian Army Combat Service Support (CSS) Battlefield Operating System (BOS) which also groups these roles together.

The broad emerging technologies likely to provide threats and opportunities for sustainment between 2020 and 2040 are classed as:

- Simulation and synthetic environments;
- Human factors and integration;
- Alternative energy and power sources (including electric drive trains);
- Automation and robotics;
- Tactical medical Command & Control (C2);
- Biotechnology; and
- Communications IT [2, 6, 11, 12, 14].

To these we add technological opportunities based on improved protection technologies (active armour, electric armour, better materials [nanotubes, composites, ceramics], improved vehicle level electronic warfare and improved Chemical, Biological, Nuclear and Radiological (detectors and protection) because B-vehicles (non-line of battle vehicles) can also be protected. From the previous DSTO study [1, 2], the candidate items for the TO dimensions are knowledge of requirements, efficiency of usage and wastage rate and to these we add knowledge of own force positions (identified as being important to protection but equally relevant to sustainment) to both strengths and weaknesses and high quality soldier care to strengths (as we doubt that Australian Army will provide low quality soldier care)[1, 2]. An assortment of weaknesses associated with the civilian opportunities for soldiers working in sustainment (logistics and healthcare are both areas with high civilian demand and long term trend growth in demand) are included: high wage costs, recruitment and retention problems and low casualty tolerance.

The Key outcomes of the TOWS analysis were:

- Targeting of B-vehicles, particularly by inexpensive but effective autonomous or semi-autonomous land and air vehicles, may become even more of a threat requiring a force structure that provides increased force protection to sustainment assets.
- It is plausible that de-skilling of first echelon repair and medical roles will allow more of their present activities to be carried out by generalists thus reducing the need for specific repair and medical units in the force structure.
- Increasing use of modularity, rotables, diagnostic systems and closed bonnet systems is likely to allow continued de-skilling of maintenance and repair personnel and place ever higher requirements on the logistical assets of any future force structure.
- Technology advances in supply chain management may reduce the personnel requirements for logistics of the same quality/quantity or allow a greater quality/quantity of logistics to be delivered with the same people. A plausible force structure effect of this is that growth of logistics personnel may not need to be as great as first appears necessary.

- Assisted driving or automation of driving may allow most logistics vehicles to be unmanned by 2040. A plausible force structure outcome is a reduction in required logistics personnel or a freeing of them for jobs other than driving.
- The overall force effects identified are reduced personnel requirements for logistics of the same quality or quality/quantity improvements in the delivery of logistics; increasing need for logistics support; and de-skilling of first echelon repair and medical roles allowing more of their activities to be carried out by generalists.

3.4 Communication

Communication is the ability to manage and transfer information securely between units to share useful information and enhance the appreciation of the situation [15]. Communication is likely to have even more importance in the future with the increasing use of remotely controlled (tele-operated) (not *fully* autonomous) robots [16, 17] and concepts like telemedicine [18]. The broad emerging technologies considered likely to provide threats and opportunities for communication between 2020 and 2040 were classed as:

- Electronic and information warfare;
- Tactical medical C2; and
- The hardware, software, security, communications and sensor aspects of IT (which, between them, deal with issues like decryption, encryption and transmitter geolocation) [2, 6, 11, 12, 14].

To these we add the opportunities of telemedicine and telepresence. The previous DSTO study [1, 2] indicates that the items in the WS dimensions should include reference to targeting to the right addressee, environmental propagation, link capacity, vulnerability to enemy disruption and susceptibility to intercept. Due to the particular importance of a highly educated and trained workforce likely to have considerable opportunities in the private sector we add the weaknesses of high wage costs, recruitment and retention problems, low casualty tolerance. The vulnerability of communications assets to detection and engagement means that we have added highly capable enemy weapons from the engagement section as a weakness here too. The excellent targeting and highly capable weapons strengths from the engagement section are also added to the strengths here.

The Key outcomes of the TOWS analysis were:

- Sensor improvement and integration coupled with precision munitions could, lead to a situation where high value transmissions need to be made remotely from units. This may lead to higher logistical requirements on the future force structure for expendable transmitters/repeaters.
- Improved intra-section communications and the fielding of Identify, Friend or Foe (IFF) technologies could, plausibly, lead to a further decluttering of the battlespace. This may lead to a more dispersed force structure and make it more important for small teams to have the support necessary to survive on the future battlefield as they will be further from other units.
- Autonomous robotic vehicles are feasible but appear unlikely to be acceptable.
- Encryption is likely to continue to overmatch decryption.

- Protection and disruption of communications with semi-autonomous robotic vehicles could, become very important. The force structure implication of this is that electronic warfare assets may need to be forward deployed and much more distributed than they presently are.
- It is plausible that telemedicine will develop to the level that diverse and highly specifically skilled medical experts (for example, surgeons, anaesthetists, dentists, psychologists, etc.) will operate from out of the theatre of combat, with only generalists in the force structure within the combat theatre or within the force at all.
- Telepresence may have effects beyond telemedicine. It is plausible that many headquarters functions presently performed in theatre could be conducted in non-deployed Australian based headquarters support units. It is also plausible that Australian (or internationally) based specialists may telecommute to deployments in 2040 apart from the possible need for maintenance.

There have been many improvements in communication and are likely to be many more but it is difficult to see fundamental changes to force structure coming out of this area. Improved battlefield communication has allowed armies to do what they do better rather than to change what they do.

3.5 Protection

Protection is defined as the ability of the force to reduce the effect of potential hazards to the conduct of safe military operations in the operational environment [15]. The broad emerging technology areas that are likely to provide opportunities for protection in the years between 2020 and 2040 are classed as:
- Improved protection technologies;
- Simulation and synthetic environments;
- Human factors and integration;
- Alternative energy and power sources; and
- Automation and robotics [2, 6, 11, 12, 14].

Threats for protection are likely to come from automation and robotics (such as inexpensive and effective autonomous and semi-autonomous air and ground vehicles); IT hardware (such as small, low cost, high quality pattern matchers); and precision and direct weaponry [2, 6, 11, 12, 14]. The key WS dimension items identified by the previous DSTO study were knowledge of the positions of own forces (fratricide prevention), protection against the environment (most importantly armour, mine protection and Chemical, Biological, Nuclear & Radiological protection), signature (ease of detection across the electromagnetic spectra and by sound) and self-defence capacity (active defence)[1, 2]. To these we add 'ability to position forces well' as terrain is often the most effective armour and 'highly capable weapons' as the level of protection needed depends on the level of threat. The ability to identify uniforms and vehicle types is another weakness (suggested by the threats).

The key outcomes of the TOWS analysis were:
- Armoured vehicles could become more robust to organic infantry anti-armour weapons and off-route mines. Future force structures will need to give infantry

access to supporting fires to ensure they remain able to survive engagements with light armour.

- Top attack protection from shaped charges and explosively formed projectiles could improve sufficiently to render ineffective systems that rely on roof penetrations using these munition types. To be robust to this possibility future force structures need to provide access to indirect fires that are not reliant on bomblets.
- Armour vehicle protection may overmatch the anti-armour missiles and autocannon carried on light armoured vehicles. A robust future force structure needs to provide continued access to armoured fighting vehicles with a sufficiently capable main armament to overmatch these protection improvements. Such vehicles are likely to be dominated and defined by their main armament.
- Protection against inexpensive autonomous or semi-autonomous robotic vehicles could become very important by 2040. Advances in pattern matching and robotics could be sufficient by 2040 to allow inexpensive mobile "mines" able to identify, target and engage Australian military vehicles and uniformed personnel. Protection against such threats is likely to include sophisticated sensors, active defence and electronic warfare and be vehicle mounted. Robust force structures would make such vehicle bourn protection available to infantry.
- It is plausible that the prevalence of vehicle bourn Improvised Explosive Devices's (IEDs) will increase with the advent of robotic drivers. Robust future force structures will be able to deploy sufficient electronic warfare capabilities to small units to jam semi-autonomous robotic vehicle bourn IEDs and be able to deliver the engineering support needed to provide stand-off distance against autonomous vehicle bourn IEDs, particularly at static checkpoints.
- It is plausible that reduced noise and heat signature will make vehicles less detectable thus allowing vehicles to work more closely with infantry.

The fundamental question for protection systems on vehicles is whether they can remain mobile and still overmatch engagement systems. This question needs to be considered separately for A-vehicles, B-vehicles, air vehicles and personnel as the practical protection systems and likely engagement systems vary markedly between these classes. A victory of protection over engagement leads to mobile warfare whereas the opposite has historically led to static or unconventional warfare where protection is provided by fortifications or a retreat into complex terrain.

3.6 Movement

Movement is the capacity to relocate units to provide useful transfer of capability and assets to conduct military actions [15]. The broad emerging technology areas that are likely to provide opportunities for movement in the years between 2020 and 2040 were classed as:

- Automation and robotics;
- Human factors and integration;
- Electronic and information warfare;
- Alternative energy and power sources;

- Tactical medical C2; and
- Space systems [2, 6, 11, 12, 14].

The previous DSTO study [1, 2] provided a good set of candidate dimensions for movement: navigation capacity; terrain mobility; number of transport lanes; availability of transport; turn around time; carrying capacity per vehicle; vehicle range; and breakdown rate.

The key outcomes of the TOWS analysis were:

- The increasing usage of highly capable sensor networks and the likelihood of decreasingly efficacy from camouflage and obscurant technologies is likely to make speed more important on the future battlefield. The force structure implication is that it may become necessary to provide the capacity to mount all infantry at the same time.
- More movement by more vehicles is likely to produce an increased logistical burden so the future force will need to have strong logistics capabilities built into its structure.
- There will be likely increases in carrying capacity per vehicle and vehicle range and a lowering of the breakdown so the increases in logistical needs may not be quite as extreme as they first appear.

3.7 Decision Making

The core function of decision making relates to the ability to make fast, high quality decisions that enable the force to operate to its best capabilities. Military mistakes can be damaging to those who make them but it has been suggested that the more varied and deeper the mistakes of one side and the more diverse the suite of sophisticated technologies in use by the other, the more chance there is of a disastrous situation developing for the mistaken side [19]. In effect, technology can be seen as magnifying the effects of skill differentials on the battlefield [19]. Mistakes can be made in all the functions mentioned in this paper but decision making is the area where errors have the potential to have adverse outcomes. It is also the area where personnel selection and the quality of their training and experience are most likely to overwhelm the effects of new technological aides. However, the importance of this area means that it must be considered.

The broad emerging technology areas that are likely to provide opportunities for decision making in the years between 2020 and 2040 were classed as:

- Simulation and synthetic environments;
- Human factors and integration; and
- Decision aids enabling better decision making (the hardware, software, security, communications and sensor aspects of IT; automation and robotics; alternative energy and power sources; and space systems). [2, 6, 11, 12, 14]

The previous DSTO study [1, 2] lists operational tempo, information manipulation (including data fusion), professional mastery, pool of stored information and device accessibility as the important elements for the WS dimensions. We replace pool of stored information and device accessibility by accessibility of storage and add an extra weakness: micromanagement. This last weakness is a threat to distributed decision making that is likely to become more tempting as communication capacity increases. In military cultures it is particularly insidious. For example, before World War I, much German ink was spilled criticising *kadavergehorsamkeit* (zombie-like obedience)[4] [20] p. 309 but during that war German troops, on the whole, took initiative on the battlefield whereas much British blood was spilled through a tendency towards excessive command rigidity and a culture of unthinking obedience and inertia below the non-commissioned officer level [20] p.310. On the battlefield, friction leads to the rapid collapse of detailed plans and the cognitive load on a commander in the midst of this fluid and constantly evolving situation will always be too great to effectively micromanage all aspects of the formation. The information should be available to small teams to help them achieve their tasks but they should be independent [21].

The key outcomes from the TOWS analysis were:

- Distributed decision making needs to be built into the force structure. Commanders of small teams need to be trusted and they need to be provided with the information that enables them to make the best decisions possible and to integrate their actions with those around them. The force structure needs to be built around informing all decision makers, even junior ones, of the intent of the commander. This ensures that communication and intent is understood and allows adaptive structures should lines of command become broken.
- Technology may give the capacity to construct force structures that can be used by commanders like the elements are automations in a computer game. Such choices need to be avoided as strongly as is possible. Centralised decision making models where every action needs to be cleared with a central authority are likely to be anathema to successful achievement of the goals given to future land forces.
- Storage and accessibility of information coupled with operational tempo may lead to low professional mastery of the skills needed to make decisions in light of the additional information. Force structures need to address this by ensuring that there is adequate slack in the system for personnel to be well trained.
- Structure and training need to be clear enough that even with distributed or devolved decision making, staff are aware and capable of decisions that they are able to make.

3.8 Population Support

Population support operations from Adaptive Campaigning are described as "actions to provide essential services to effected communities. The purpose of these actions is to relieve immediate suffering and positively influence the population and their

[4] This occurred during the debate between the *Normaltaktik* and *Auftragstaktik* schools. Proponents of the former worried that the move to open order needed to counter the deleterious effects of growing firepower on closed order infantry formations left soldiers dangerously alone and that only standardised set-piece procedures that were repeatedly drilled until they became second nature could save the offensive [43, p.95] The latter argued that training for independence of action was what was most needed [43, pp.95-96]. In the end a compromise was implemented with repetitive drill and independent action [43, pp.98-103].

perceptions."[3]. The WS elements in this area are weighted to human populations due to the nature of the operations conducted in this area and the outcomes required. The risks of not conducting these non-traditional military operations effectively "creates opportunities for adversaries to gain influence over the population or to seek to profit from a destabilised situation." [3]. Although population support is not traditionally a core function of the military it has over the evolution of operations conducted become a more and more intrinsic part of the job and a necessary undertaking in order to meet the required objectives.

The broad emerging technology areas that are likely to provide opportunities for population support in the years between 2020 and 2040 were classed as:

- Non-lethal technologies;
- Structural materials;
- Biotechnology; and
- Tactical medical C2 [2, 6, 11, 12, 14].

The Key outcomes from the TOWS analysis were:

- Any future structure needs to be adaptable and needs to be able to absorb the new skills, concepts and associated functions as well as maintain basic ones in case of technological failure.
- There will need to be force elements which are trained to work with the population as their main duty.
- These functions are additional to the traditional military role and may become part of the new role.
- Force elements would need to be provided which can undertake this role. Changes to the delivery of these services would require changes to the force structure and provide new/alternative chains of command.
- The need for additional/alternative functions will likely provide opportunities for new ways in doing business with new elements providing functions or for multi-tasking existing force elements in different roles.

3.9 Indigenous Capacity Building

Indigenous capacity building is described as including "actions taken by the Land Force to assist in the development of effective indigenous government, security, police, legal, financial and administrative systems. It sets the conditions for transition to indigenous government…" [3]. Although indigenous capacity building is often included in the aim of an operation, it has not been a function of the military itself. This will likely change as the military provides the first line of this capacity prior to others providing more long term functions. The broad emerging technology areas that are likely to provide opportunities for indigenous capacity building in the years between 2020 and 2040 were classed as:

- Automation and robotics;
- Structural materials; and
- Alternative energy and power sources [2, 6, 11, 12, 14].

The Key outcomes from the TOWS analysis were:

- Any future structure needs to be adaptable and needs to be able to absorb the new skills, concepts and associated functions as well as maintain basic ones in case of technological failure.
- Any amended force structure allowing for less manpower as a result of technological advances will still need to provide for greater presence with the population.
- Any force structure will need to provide for indigenous training in capabilities provided and for first hand support to local governments and agencies.

3.10 Population Protection

Population protection operations include "actions to provide immediate security to threatened populations in order to control residence, identity, movement, assembly and the distribution of commodities, therefore setting the conditions for the re-establishment of law and order." [3]. Although population protection has been undertaken by the military it is often on an ad hoc basis and not as formally practiced or prepared for. This will change as operations have this as a mandate and as new concepts and training regimes in this specific function are prepared for.

The broad emerging technology areas that are likely to provide opportunities for population protection in the years between 2020 and 2040 were classed as:

- Non lethal technologies;
- Precision and direct weaponry;
- Human factors and integration;
- Biotechnology; and
- Tactical medical C2 [2, 6, 11, 12, 14].

The Key outcomes from the TOWS analysis were:

- Any future structure needs to be adaptable and needs to be able to absorb the new skills, concepts and associated functions as well as maintain basic ones in case of technological failure.
- Changes to structure to allow greater flexibility in new demands – might provide for a dynamic structure at the lower levels
- Future changes to delivery of medical services and decision making may impact on the ability to undertake this function.
- Enhancements to medical support will engender population and allow greater spread of operations and types of operations in areas not previously tackled.

3.11 Public Information

Public information is considered to support all the elements of Adaptive Campaigning and is a key factor for success. It is considered to be "a collection of capabilities brought together and focuses to inform and shape the perceptions, attitudes, behaviour and understanding of targeted population groups…" [3]. Public information is an important factor in working with the population and is required from the beginning of or immediately prior to any operations in order to allow the previous 3 Adaptive Campaigning operations types to succeed. The broad emerging technology areas that are likely to provide opportunities for public information in the years between 2020 and 2040 were classed as:

- Hardware, software, security, communications and sensor aspects of IT; and
- Electronic and information warfare [2, 6, 11, 12, 14].

The key outcomes of the TOWS analysis were:

- The force structure may become so reliant on the technologies for the dissemination of information to the public that it cannot function without technical assistance. As a result, any future force should be designed with both the future capabilities AND their non availability in mind. This would require elements who are specialists in communicating the necessary information and dealing direct with the population.
- There is a risk of becoming dependent on the technology such that decisions are reliant on the integrity of the information being collected/disseminated. The force needs to be able to monitor and ensure its integrity and its acceptance which cannot be done by technology and will require specialists in these areas.
- The structure will need to integrate and overlap this function with other agencies in the provision of this kind of information.

4. Assessment of Possible Technological Impact on Army Unit Types

The discussions in this section represent a starting point from which further work with military experts from appropriate areas is necessary before any final conclusions can be reached. Figure 2 gives an indication of possible impacts by function and army unit types as a result of technological developments, as a traffic light diagram. The authors look at how the plausible key technological developments may impinge upon each of a (somewhat arbitrary) set of the functional groupings in the future land force. These functional groupings look very much like Battlefield Operating Systems but are not exactly the same as them and are as such not exhaustive and in the time since the work was undertaken some groupings have changed for future forces. However, roles will still exist and could be mapped into expected roles and structures. Before too much weight is placed on the tentative conclusions that are presented in this section it would be necessary to talk with representatives of each of these functional groups. This is required because it is certain that some issues of merit have been missed and is rather likely that some canards that are *bête noires*[5] of knowledgeable stakeholders will have been included. It is also noteworthy that there has been insufficient time and understanding by the authors to present even a cursory discussion of the special forces functional groupings appearing in Figure 2. There is variation in the depth in which different functional groupings have been considered as lack of time and access has meant that the authors have had to use their own

[5] Literally "black beast" – a term for something someone dislikes very much.

(often small) expertise rather than that of subject matter experts; for example, less detail in combat engineering versus more detail in surveillance and reconnaissance.

4.1 Artillery

The persistence of artillery means that it is likely to remain relevant to force structures until 2040 at least. This does not mean that the equipment used by artillery units, their internal force structures and their relationship to the rest of the force will remain unchanged, just that there will still be a need for the role.

4.1.1 Mobility's Catch 22

Self-propelled guns and towed tubes both have their failings and no obvious technology on the horizon will fix these. In operational mobility, towed tubes have an advantage as they are easily moved by battlefield aviation assets. At the most basic level of tactical mobility, which is needed to avoid counter battery fire, self-propelled artillery has a massive advantage. Plausible technological advances in sensors, integration and engagement are likely to make counter battery fire more responsive, more accurate and more destructive in 2040 than it is now. The best way to avoid being destroyed in an engagement is to not be there when the rounds hit. If the tube is there then its survival chances are improved by armour, particularly as electric armour is likely to offer considerable protection against shaped charge and self-forging projectiles by 2040. In both these respects, self-propelled artillery has an advantage over towed-tube artillery.

4.1.2 Automation

The main signature presented to the enemy by artillery units is the launching of projectiles from tubes. Even though most forces would like to target C2 assets their counter battery fire ends up concentrated on these tubes because they are detectable. Robot systems in loading and driving functions open up the possibility that not only may the crewing levels for each tube be reduced but that the crew may not need to be with the vehicle at all by 2040. The United States (US) Future Combat Systems was targeted at delivering much of this automation from 2016 however the program was ended in 2009 and elements continued under different specific programs [22, 23]. If tubes were inexpensive enough and sustainment was proficient enough they might almost be disposable. Without the need to carry and protect people self-propelled guns may become considerably lighter but it is unlikely that they will be light enough to be helicopter mobile. Such automation and remote control may allow a force structure that is concentrated around protecting the command, control and supply assets associated with the artillery.

4.2 Air Defence

It seems plausible that both the airborne threat and defence environments of 2040 will be more continuous than they have ever been. Air threats are likely to manifest themselves from new sources such as operator crewed aircraft carrying stand-off munitions; un-crewed semi-autonomous aircraft carrying stand-off munitions or directly attacking ground forces with missiles, rockets, bombs and cannon; and autonomous 'intelligent' flying munitions. Other air threats (such as missiles, rockets and shells) that are presently in existence are more likely to be clearly seen as air threats in their own right, rather than as an element of a ground threat, simply because there will be active defences against them that allow them to be engaged separately to the unit from which they originated. Air defences are likely to move away from present bi-capabilities of high capability sensor directed assets (such as radar, infrared or command to line of sight-guided missiles and guns) operated by air defence units and very low capability non-sensor directed assets (such a 0.50 calibre anti-aircraft machine guns) operated by other units. It is credible that there will be a continuum of responses due to the lower size, cost and operator complexity of future sensor systems. This continuum could conceivably stretch as shown in Figure 1 below.

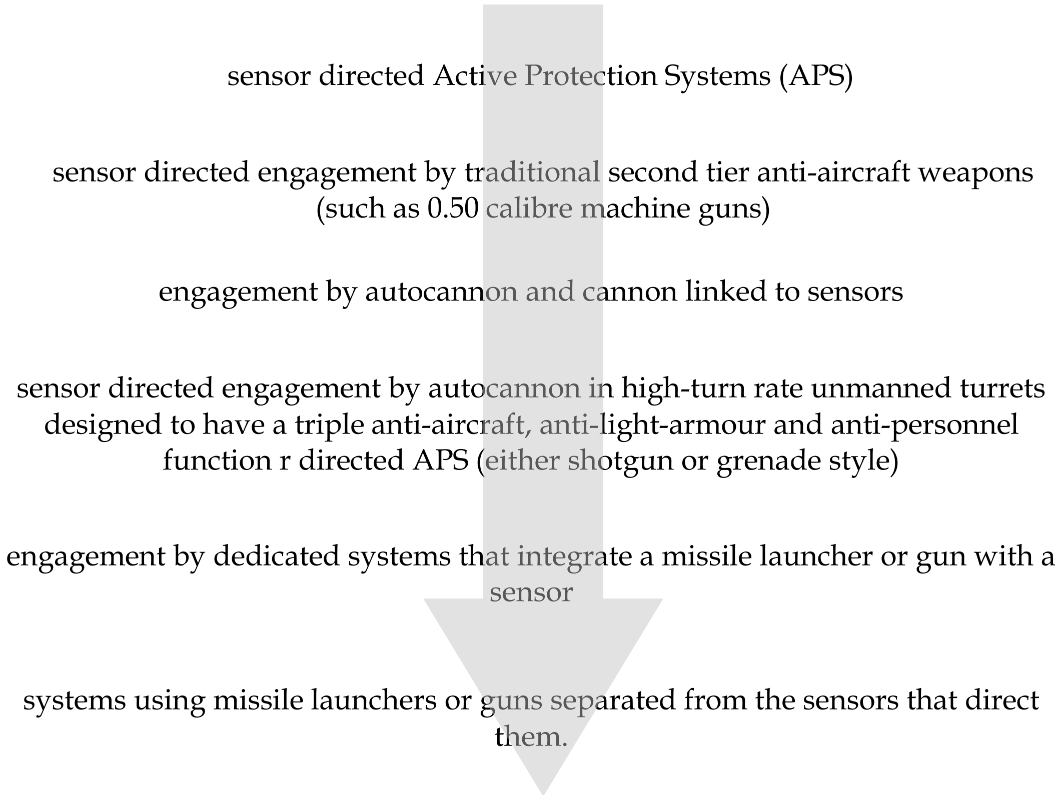

Figure 1 Continuum of possible technological advances in air defence engagement

The numerousness of plausible future air threats[6] make it critical to provide ground based air defence to future land forces. However, this does not mean that air defence must be kept as a separate functional grouping in a future force structure. Many of these capabilities will need to be distributed at small unit level. An important issue in considering whether to keep air defence as a separate functional grouping in the future force structure is whether future close air defence guns for land systems will be able to be

[6] These plausible future air threats could be from stand-off missile and UCAV (unmanned combat aerial vehicle) programs and the credibility of improvised flying bombs becoming available to asymmetric opponents as guidance and control systems become more capable and less expensive

integrated into standard infantry fighting vehicles or whether they will need to remain in separate platforms. While it seems plausible that the former will be the case it would be imprudent to remove a specialisation from the future force when it may still require specialisation. The future structure of air defence forces will need to incorporate an ability to respond to plausible future air threats to the force.

4.3 Armour

The manner in which key technological developments alter the engagement versus protection trade-off is the most important issue in deciding whether armoured units are beneficial to the future force structure. Technological developments relating to communication and mobility are also important, particularly in whether they facilitate the automation of certain armour functions.

Secondary concerns which affect the force structure for armoured unit are the reliability, reparability and sustainment needs as they are more platform dependent.

4.3.1 Engagement versus Protection

The struggle between the capabilities of weapons used in engagement and the techniques used to protect from them is an enduring feature of warfare. When the balance tips towards mobile protection, warfare opens up as adversaries care less about presenting a signature above the discrimination threshold. When it tips towards engagement, warfare becomes more static as combatants seek to keep their signature below the discrimination threshold or use non-mobile protection.

4.3.2 Automation

Armoured systems are already automated systems. Mechanical power is required to move the weight of armour required for protection and the mass of a weapon capable of dominating the battlefield. It is also needed to move this package with sufficient acceleration and maximum velocity to be survivable on the battlefield. Automated fire control systems are necessary for gunners to be able to accurately target their adversaries and automated stabilisation systems are linked to these to allow firing on the move. The typical crew of five in the original main battle tanks reduced to four. Numerous automated sensor systems allow crew members to 'see' in spectra or at light levels that the human eye cannot see in by translating signatures in these into crew interpretable information. However, for this generation of armour professionals, the automatic loader is the stand out example of automation.

When the T-64 was introduced it became the first production tank with an autoloader. In a redesign with the loader removed, extra armour was then able to be added to improve the protection of the smaller crew. Minimisation of protected volume remains an important benefit of autoloaders and can be used for improved crew survivability and/or weight reduction[7]. In practice, many actual automated loading systems limit crew survivability both by increasing the possibilities for catastrophic explosions and by reducing the initial rate of fire for systems with a calibre less than 125mm[8]. Automatic loaders also add moving parts to the loading system and so make it less reliable and more prone to breakdowns. There is also a possible reduction in visual coverage. Present technology has not eliminated this disadvantage but it is highly plausible that improvements in sensor and information presentation technologies give two crew members sufficient situational awareness by 2040. Other problems with the automation of the loader role could be the removal of a fourth man who can undertake maintenance, sentry duty, and the role of driver or gunner. As the armour of vehicles on the battlefield improves it is quite likely that traditional gun systems will need to increase in calibre, possibly to 140mm or 152mm, to achieve penetration. This will make human loaders redundant as people are simply not strong enough to lift these rounds in confined spaces. Furthermore, systems like rail guns and liquid propellants, which may replace traditional gunpowder, require automated loading of the propellant and/or shell.

The advances that are likely to occur in automated driving systems will mean that the drivers of armoured vehicles will almost certainly have some level of robotic assistance by 2040. Manoeuvring an armoured vehicle on the battlefield is likely to be amongst the most challenging problems facing the full automation of driving systems as the robotic entity doing the driving would need to have taken into account the need to use terrain to provide protection and manoeuvre the vehicle to allow engagement by its weapons. It is still entirely plausible that technology advances will make it possible to compress the functions of driver and commander, although extreme care needs to be taken in overloading the cognitive capacity of the commander with the details of driving when they should be used in deciding how best to fight the vehicle. What is certain is that increasing automated aids will be provided to vehicle drivers and that, increasingly, the information that drivers use to control their vehicles will arrive from sensor and interpretation systems that stand between their senses and the outside of the vehicle.

Lighter armoured fighting vehicles are already available in which the turret is separate from its operators. This allows the commander and gunner to sit within the hull of the vehicle. Their protection is improved, the protected volume (and therefore the weight of the vehicle) is decreased and the silhouette can be lowered without lowering ground clearance. Technology advances in penetration may make it increasingly vital to concentrate protection while advances in sensors, communications and information presentation make it increasingly possible to maintain adequate levels of situational awareness while the crew remains under armour. There an outside possibility that rail guns will be deployed that can penetrate the armour of opponents vehicles but need so

[7] Modern autoloading tanks such as the T-90, Type-90, Type-98 and Leclerc are all in the 45 to 55 tonne range whereas modern tanks with human loaders such as the M1, Challenger and Leopard 2 are all in the 55 to 75 tonne range.

[8] For 120 mm or 125 mm rounds automatic loaders typically manage 10 to 12 rounds a minute over all terrain and for as long as there is ammunition. Human loaders start off with a rate of more like 15 rounds per minute but tire rapidly and slow if the terrain is rough. Of course most engagements require only a few rounds to be fired before there is a break so human loaders are faster than present autoloaders for 120 mm or 125 mm rounds in practice.

much support for the barrel that they need to be mounted in the hull. In all of these cases the crew would be contained in the hull and would rely on external sensor systems to channel information to them. These sensor systems are likely to be targeted. Already there are air defence artillery rounds, like the Oerlikon Contraves /Rheinmetall Defense 35 mm x 228 that are being trialled which strip sensors from opposing armoured vehicles. There are likely to be moves to protect sensors from such attacks to enable crews to stay under armour as the effects of such systems on the heads of crews would be likely to be devastating.

This leads to the question of whether communications will become secure enough from jamming that armoured vehicles can be fought using crews that are not actually present on the vehicle.

4.3.3 Conclusion

Automation, improvements in robotic driving, changes to engagement systems and improvements in aids for situational awareness could lead to the reduction of tank crews from four to three or even to two. There would need to be robust proof that the situational awareness of the crew was not disastrously degraded before such changes were implemented. The force structure implications of a reduction in crew size are that alternative arrangements would be needed for the secondary roles in security and maintenance that these crew presently undertake and that the personnel rotation system would need to be more able to provide emergency replacements for incapacitated crew members as there would be less robustness. The force structure implications of remote control of vehicles would be the need to provide a secure (probably second echelon or second line) area of operations; the need to provide the crew with mobility separate to their (remote controlled) armoured vehicle to enable them to evade enemy manoeuvre elements and supporting fires; the need to minimise signature, possible through multiple remote transmitters, to minimise the chances of detection; and the possibility that one crew could operate more than one vehicle or that crews could operate variable numbers of vehicles allowing minimal oversight of those out of action but close oversight of those in action. The main effect of the last point is that there may be many more armoured vehicles than there are crews by 2040.

4.4 Combat Engineering

The combat engineers primary roles is to provide geospatial, mobility, counter-mobility, survivability and sustainability support to Army, and their second role is to fight as infantry [24].

The combat engineers will be affected by many of the emergent technologies due to the broad nature of their roles. Civilian core functions and their associated technological advances will need to be added to the engineers. This will include technologies such as new and alternative energy sources and power supplies, some of the biotechnologies and new or advanced structural materials. As a result of this there may be a requirement to include additional specialities within the group.

The need for protection of the engineers may increase with the likely threat of standoff or robotic area denial weaponry. However, countering this will also be the improvements in detection and concealment technologies. It is difficult to say at this stage what will and will not be a counter effect to a new technological threat. Certainly the role and position of the Engineers will require that they need protection while undertaking specific tasks and this protection may indeed be provided and significantly enhanced by the anticipated technologies. These may impact on the structure by requiring or allowing different ways of providing this protection such as providing better protection with less manpower due to better sensors/detectors, automated or autominimise systems and advanced weaponry.

Of particular concern is the reliable and timely supply of equipment on operations to undertake specific and specialist tasks. The advances and automation of the sustainment chain including logistics supplies may affect the process and structure that is currently used to ensure that the necessary equipment arrives as needed. It may be that this factor needs to be designed into any future sustainment systems as the new technologies are implemented.

Many of the issues faced by the light infantry will also be faced by the engineers in that aspect of their roles as discussed in 4.6.

4.5 Intelligence

Intelligence is likely to be strongly effected by key technological advances in information collection, population support, indigenous capacity building and public information.

While intelligence is a critical part of any force that is to conduct joint land warfare against a force that is a peer in skills and technology it is both critical and requiring of different intelligence types, in carrying out stability operations where the opponents use asymmetric methods. Stability operations are often conducted in chaotic situations where there are many possible opponents. Appropriate intelligence preparation of the battlefield must give the commander an idea of the relationships between the different factions and fractions faced in the society, as well as accurate indications of the threats posed by and importance of key figures and groups. These are very difficult jobs and, while technology may provide tools like social network analysis toolboxes and more rapid access to the communications intelligence, it will not replace the human brain or remove the need to build relationships with locals.

The critical importance of appropriate intelligence to conducting the Adaptive Campaigning lines of operations (in addition to joint land warfare) means that intelligence assets will continue to, and require to be, essential.

4.6 Light Infantry

The main role of the infantry is to undertake warfighting and close combat with every soldier skilled in both lethal and non-lethal force across the entire spectrum of conflict including peace operations and providing security. The light infantry is noted by not having integral armoured assets, however is capable of battlegrouping with a range of combined elements [25].

The effects of new technologies to the structure of the infantry appear to be in allowing it to become more flexible and independently mobile on the ground with the ability to be regrouped for different tasks. An additional component to the traditional fighting roles will be increasing the functions which will deliver the civilian support based functions of Adaptive Campaigning. In the longer term, these will require additional training and possibly structure changes to accommodate these additional roles. The additional feature of technology support in these areas will require training such that the additional roles can be undertaken without losing the ability to undertake their main role.

In the longer term, personal armour may develop such that infantry may become more able to survive indirect fire weapons and individual weapons whilst still needing further protection from crew serviced direct fire weapons. So there may be an ability to form smaller more mobile squads in certain situations. However the need for protection from future larger calibre direct fire weapons may limit some of these changes. Technological advances may reduce mortality rates and the severity (and possibly even number) of injuries however it is likely that the only impact on force structure may be to reduce the need for as many "reserves".

The advances in communications will impact on the infantry particularly at the small unit, IFF and "to vehicle" or "to support" communications. These advances, including the probability that encryption will still out delay decryption, mean that the infantry will have greater flexibility and scope of movement including moving out of "line of sight" for communications in urban environments. The breakthroughs and cost reductions likely in the IFF technologies are likely to allow greater scope of movement of forces on the battlefield without the need to be in sight in order to reduce fratricide levels. In addition, and especially for the infantry, there may be a greater decentralisation of Decision Making to those on the ground with the opportunity for smaller delays and response times and less "double" handling of information.

The likely advances in sensor technologies coupled with precision and direct fire weaponry will possibly alter the way the platoons and sections are structured to carry out their duties. There is a likelihood that these weapons will likely substantially increase the impact and firepower from, as well as becoming organic to each group. This will likely affect the range of tactics which might be employed with each element.

A threat likely to face the infantry will be the use of autonomous robotics likely to be used as area denial weapons. Although not a direct impact on the structure of this unit type, it may result in the implementation of alternative counter denial, protection technologies or force structures in order to minimise their impact.

4.7 Motorised Infantry

The motorised infantry differs from the light infantry in that it is designed such that using organic motor transportation all its personnel, weapons and equipment can be moved at the same time. The use of the motorisation is to position the combat forces and weapon systems for the conduct of dismounted operations [26].

Therefore apart from effects to this element from core functions and technologies impacting on the motorised aspects, the rest of the potential impacts are the same as for the light infantry in Section 4.6.

The biggest impact to the motorised infantry will be from the vehicle sustainment. Advances in electric drive and fuel cell technologies will begin to replace the internal combustion engines and affect the types of vehicles available for these purposes. There are however many hurdles to be overcome by these new technologies which may delay their introduction. In addition to these, moves towards modularised components and autonomous or semi-autonomous driven vehicle systems will have an impact.

Each of these is likely to impact on the structure of the motorised infantry in its ability to maintain these vehicles, conduct training to understand and apply the technology (or integrate it to conduct operations) as well as in their sustainment for maintenance. The advent of the modularised and autonomous or semi-autonomous driving systems may require fewer soldiers to undertake the same current tasks.

For this group, there is an additional grey area which is likely to impact on their force structure or existence as a separate entity in the future. With the advent in many new vehicle based technologies, coupled with the advances in weapons technologies and armour or vehicular protection, there is likely to become a very fine line between the vehicles currently used by the motorised infantry and those used by the mechanised infantry. It is likely that in the 2030 – 2040 timeframe that these vehicles will very similar if not “one and the same”.

4.8 Mechanised Infantry

The mechanised infantry functions are similar to those of the light infantry, however, they have armoured assets such as armoured personnel carriers organic to the unit and a mechanised unit is one which is defined as a standard grouping of armoured personnel carriers and infantry. The tactics of the mechanised infantry alter from the light and motorised as they have the ability to utilise the armoured personnel carriers [25].

Again, however, most of the impacts specific to this group which will differ from the light infantry will come in the armoured personnel carrier and core functions relating to that area as the rest will be similar to those impacting on the light infantry.

As with the motorised infantry, the biggest impacts to the mechanised infantry will come from the advances in vehicular armour, weaponry, sustainment, and autonomous and semi-autonomous driving. In particular, the greatest effects to the structure will be the potential to alter the crew capacities and roles.

4.9 CSS

The combat service support functional grouping is the most diverse of all the functional groupings. It is unsurprising that it is the one with the most possible changes to force structure resulting from potential key technological advances. The major changes in this area mostly arise from de-skilling the workforce due to technological advances, either due to the capacity to centralise these skills (e.g. telemedicine or repair in the factory) or their replacement by technology (e.g. point of care testing or replacement rather than repair), and the labour replacement capacity that technology allows (e.g. automated driving). Logistics is likely to become more important while requiring fewer people but more equipment and more protection. Repair and service units may become less skilled due to increased reliability and usage of rotables but more necessary as increased automation removes crews who would once have performed low level maintenance and repair. Deployed health care units may become smaller and more generalist while using technology to access a larger pool of more specialised contractors.

4.9.1 Automation of Logistics

Long before it is technically feasible for autonomous combat vehicles to fight on future battlefields it will be feasible for logistics vehicles to drive themselves with little or no human intervention. Furthermore, existing technologies in mathematical algorithms, software, hardware and interface technologies need only be combined to make automated scheduling with minimal human intervention possible. Supply chain management technologies are in a period of rapid advance and may be coupled with vehicle automation in the near future to produce almost fully automated warehousing. Coupled with the automation of inventory and delivery tracking using information and positioning technologies these advances mean that the same level of service may be provided in the future by radically fewer logisticians.

Another effect of increased automation of vehicle operation is that the number of crew per vehicle will fall. It may even fall well below one in some situations, especially in logistics. This will mean that the crew members who once performed maintenance and low grade repairs on their vehicles will no longer be present. Force structures need to adapt to this situation. One solution may be to establish mobile low grade service and repair units.

4.9.2 Increasing CSS Protection Requirements

Increasing technological sophistication is likely to make deep strike more possible on advanced battlefields. Also the spread of technology is likely to make attacks by asymmetric forces more deadly. Both of these factors mean that combat service support units will need to be increasingly able to fight in order to defend themselves on future battlefields or be expendable.

4.9.3 More Logistics and Fewer Complex Repairs

A combination of increasing modularity, allowing easier replacement using rotables, better diagnostic systems and increasingly effective closed bonnet systems, make it plausible that the force structure of combat service support will need to shift away from repair in the field and towards greater capacity to ship rotables into and (to a slightly lesser extent) out of theatre. This will mean a greater emphasis on logistics in the force structure at the cost of repair units. Overall there will almost certainly need to be a higher level of quality and quantity in logistics provision.

4.9.4 Health Care: More With Less

Several technological trends are likely to reduce the numbers and diversity of medical personnel required to be present in deployments while maintaining or even improving the level of care. Telemedicine, telepresence and point of care testing technologies are likely to allow lower numbers of more general healthcare staff in the force structure to leverage off improved methods and greater access to outside help to provide the same quality of care. This does not mean that less medical personnel will be *involved* in deployments, just that less will need to deploy. Telemedicine is likely to allow specialist surgeons to be sourced from anywhere with appropriate facilities. Telepresence is likely to allow psychological support services to be provided from outside of theatre. Point of care testing is likely to make diagnosis and treatment of infections and diseases a considerably less skilled job (and this is likely to be one of the major effects of 'nanotechnology' on the future force). Deployed specialist health care services are underutilised or utilised in sub-optimal ways most of the time, as they need surge capacity to cope with emergencies. An ability to contract this work to teams remote from the battlefield could mean an increase both in efficiency (less force elements being used sub-optimally or not being used at all) and in robustness (greater surge capacity). The force structure implication is the possibility for a reduced complexity in the health care elements of the deployed force and the capacity to contract these roles out to established teams in the civil sector rather than retain skilled individuals in the reserves.

4.10 Aviation

While there are likely to be considerable changes in the technology involved in aviation over the years to 2040 it seems credible that there may be little change in the force structures of aviation units. Aviation units duplicate many of the structures that CSS units provide to the rest of the army because of differing tolerances for error. Many of the major changes in aviation technology are likely to relate to whether aircraft are piloted by on-board pilots, off-craft pilots or are autonomous. As the majority of the force structure for aviation is built around servicing, maintaining, arming and supplying the aircraft rather than actually flying them such changes are likely to have a minimal impact on the force structure. The issue of who should control pilotless aircraft is relevant to force structure but this is more a political than a technological issue so it is not addressed here.

4.10.1 Proliferation of Pilotless Aircraft

Pilotless aircraft, both controlled and autonomous, are likely to be considerably more technically capable and very much less expensive in 2040 than they are at present. The roles filled by such craft are likely to span the range from those traditionally filled by aviation to those traditionally filled by munitions. Of the traditional aviation roles of transport, offensive support and reconnaissance the first of these is the least likely to be fully automated because of the greater requirements for aircraft control when carrying troops and the lower risk profiles of these missions. However, it is likely that there will be considerable automation.

At the outer end of the period under consideration it may be possible for automated flying pods to be involved in medical evacuation. This may give a more timely response but even in 2040 it seems unlikely that telemedicine will have advanced to the point where the present quality of care can be provided with no human presence at all. However, timeliness is an exceptionally important factor in survivability so it may be that the medical evacuation role of human operated aviation is replaced.

4.11 Military Police

From current Land Warfare Doctrine, the role of the military police (MP) is to provide commanders with essential elements of C2 achieved through the application of MP functions across the spectrum of conflict. The four key functions of the MP are: law enforcement, security, mobility and manoeuvre support, and internment and detention [27].

Many of the technologies which will impact on the MP will do so in such a way that they will not likely impact significantly on the structure as well. The greatest impacts will be seen by those technologies coupled with the integration of the civilian core functions which may be added to the MP functions. These would require greater specialisation and training in these areas and the use of the additional technologies as well as the ability to undertake these new functions with out the aid of the technologies.

In terms of the technologies which may impact on the structure and functions of the MP include the non-lethal technologies, communications, robotics and the changes to decision making protocols.

Improvements and breakthroughs in the types, reliability and availability of non-lethal weaponry will likely enhance the way that the MP deal with situations using these weapons. These improvements may also increase the situations in which they can be used. In particular there deployment in population support and protection operations is likely to become more widespread. They may also allow changes to the way in which MP use weaponry / ammunitions to undertake their duties.

The communications, sensors and information security advances are likely to allow the MP to undertake their duties with greater freedom and less line of sight communications requirements such as in urban environments. This may alter the way MP teams are structured today, particularly on operations.

Although the use of robotics is likely to be limited in this area, it is likely to impact on the structure of the MP. The use of automated vehicles will free up manpower to undertake other duties.

4.12 Surveillance and Reconnaissance

Future surveillance and reconnaissance units are likely to be most affected by technologically-based improvements in information collection and communications functions. There are likely to be continued improvements in overhead imaging, both space based and aerial, at several levels: sensor abilities; data fusion; data presentation; and communication times both of imagery to points of interpretation and intelligence to where it is needed. However, the most plausible technological treads are a continued need to fight for information; the risk of centralising the interpretation of surveillance and reconnaissance; the continuation of the importance of soldiers as sources of information; increased use of robots; proliferation of IFF; and the effects of ad-hoc networks.

4.12.1 Continuing Need to Fight for Information

Technological improvements will not remove the need to fight to bring opponents above the discrimination threshold. Reconnaissance assets will need to retain and improve their abilities to fight and continue to balance the need for protection and fire power.

4.12.2 Networking and De-skilling

Improvements in technology are unlikely to remove the occurrence of periods when the network is inaccessible, even in peace time. In war, when opponents actively seek to bring communications networks down, they will be even less reliable. Soldiers trained within a networked battlespace will still need to retain the skills to work without the network. This is especially important for soldiers involved in surveillance and reconnaissance where the reduced information flow times produced by networking will make them much more effective. Multiply redundant systems of information flow and the training needed to use them in stressful environments will be important for a robust surveillance and reconnaissance capability.

4.12.3 Soldiers as information collectors

Soldiers are important collectors of information and technological improvements outside the traditional areas of surveillance and reconnaissance are likely to improve their abilities to collect information. One way is through plausible improvements in training technologies that may make it marginally easier to learn languages and equipment operating skills. Another is through translation technologies that may augment the language skills of soldiers.

4.12.4 Robotics

Due to the likely effectiveness of unarmed robotics in some of the tasks needed in surveillance and reconnaissance it is plausible that they will be adopted on an even more widespread basis than they already are. Already, uninhabited aerial vehicles are used, especially for surveillance. With the use of unarmed robots the level of human oversight required by commanders is likely to be considerably less than for combat robots, indicating that surveillance and reconnaissance could be areas of early adoption of robotic technologies. Miniaturisation is likely to shrink the signature of robotic vehicles and make them more portable. This could considerably improve surveillance in the immediate vicinity of forces, especially in urban environments, due to micro-robots monitoring the areas around the force.

4.12.5 IFF

Improvements in IFF systems are likely to make it easier to identify own force assets in regions in which surveillance and reconnaissance is being undertaken.

4.12.6 Ad-hoc Networking

Improvements in ad-hoc networking technologies are likely to make it considerably easier for surveillance and reconnaissance assets to communicate with other forces that depend on their information.

4.12.7 Conclusion

The overall effects of the technological changes are likely to push greater surveillance and reconnaissance power into the hands of smaller units.

	Engagement	Information Collection	Sustainment	Communication	Protection	Movement	Decision Making	Population Support	Indigenous Capacity Building	Population Protection	Public information
Artillery											
Air Defence											
Armour											
Combat Engineering											
Intelligence											
Light Infantry											
Motorised Infantry											
Mechanised Infantry											
CSS											
Aviation											
Military Police											
Surveillance & Reconnaissance											
SF Elements											

Figure 2 This table presents a summary of the analysis undertaken by the authors of where Army unit types may be affected by both function and the impact of future technologies. If a unit type is heavily linked to a function then it will also likely be affected by any force structure impacts from future technologies. The interactions and possible effects on force structure are indicated by : a solid black cell is the most extreme indicator, and a hashed cell the least. Light grey is midway. No colour at all indicates that there is no anticipated effect at all on the force structure.

5. Ethical Considerations of Emerging Technologies

"Technology can be seen to promote or restrict human rights. The Information Society should foster the use of emerging technologies in such a way as to maximise the benefits that they provide while minimising the harms" – UNESCO, 2007[14].

A contributing factor to any analysis on future technologies is the integration of ethical considerations on its use prior to or in the early stages of its uptake. In terms of the Australian Defence Force (ADF) there may be considerations which might preclude the use of or use in certain ways of particular technologies. This may impact particularly on decision making to use these technologies and hence the implications that these technologies might have on the future force structures. Certainly any future force structure needs to be able to manage these considerations with potentially radically new concepts facing the Australian Defence Force. In these grey or unknown situations, careful consideration of these ethical implications needs to be given.

A good example of this is extrapolated from one given in [14], and looks at the alternative uses of future sensors which detect thermal signatures. In one respect they can be used to detect spot fires in forests or of known and identifiable enemies in obscured environments. The flip side of this is the use of these sensors in urban environments or environments where the enemy is integrated with other entities in that environment. In these cases thermal signatures intrude on the privacy of those entities in that environment. In terms of the Universal Declaration of Human Rights [14, 28], there are uses in which the use of these types of sensors will either breach this declaration or enter a very grey area. If a future structure has been designed to use technologies such as this then it will also need to consider these implications and develop strategies for use accordingly.

New technologies which are focussed in the IT domain deal with many issues including privacy and anonymity of data and technologies such as biometrics face similar ethical considerations [14]. Importantly the biotechnology developments such as enhanced human performance face even more critical issues some of which have not yet been dealt with such as robotic implants or extending human performance through technological means. These may be emerging technologies which would impact on future force structures but which may not be fully adopted or integrated into the ADF due to the ethical implications.

Another important implication is currently in the early stages and is directly related to Samsungs Intelligent Surveillance & Guard Robot (Section A.1.2), which is a stationary autonomous fighting robot with the capacity to kill people. In many respects it resembles an expensive and long ranged anti-personnel land mine. While the Ottawa Treaty bans anti-personnel landmines for signatory states (South Korea and 36 other states are not signatories) and there are similar international agreements to ban or restrict Nuclear, Chemical, Biological and Radiological weapons, The Hague Conventions dictate that there must be a determination of whether new weapons are prohibited and there has been no serious test of autonomous fighting robots. Preliminary work [29] has implied that they are legal but there are serious practical, ethical, moral, religious and public relations problems in developing and deploying autonomous fighting robots. As these issues are fought out in the international arena there will be implications for the ADF.

6. Indications of Gaps

From the TOWS analysis conducted there is no apparent unit type which would be rendered redundant in the 2020 to 2040 timeframe. However, the analysis provided indications of potential gaps arising in the current force structure. This may require the integration of new elements or amendment of current elements, resulting from changes to current roles.

In general the introduction and uptake of some of the new emerging technologies may result in the ADF being able to do more with less and the counter to that position is the potential deskilling of personnel able to undertake tasks when the technology fails or is not available. These factors are certainly likely to be present in the areas affecting vehicles (all types), CSS support including medical provisions and weaponry.

The greatest gaps in capability and structure appear to be likely in the four Adaptive Campaigning functions additional to the joint land warfare functions and with the introduction of additional capabilities and concepts particularly in this area in addition to the Australian Defence Force's traditional military roles. Apart from these a robust future force structure needs to:

- *Unify forward calls for fire from all joint indirect fire assets* as these are likely to multiply in types, increase in capacity, become more critical and yet spend more time avoiding opposition counter fires. Making all indirect fire assets available to all controllers improves the likelihood of one being available when needed.
- Be prepared to *continue to fight for information* as opponents will still be able to drop below the discrimination threshold even with improvements to detection technologies.
- *Support infantry with vehicle mounted assets* capable of penetrating armour that overmatches the capacity of any organic infantry weapon and electronic warfare and active defence assets to defeat inexpensive but capable robotic vehicles.
- Prepare for a *massive increase in the logistical requirements* of deployed forces.
- Be aware that *automated driving assistance* may allow a single driver to remotely control many logistics vehicles and that semi-autonomous robotics may allow a single soldier to control multiple uninhabited ground vehicles.
- Continue to *distribute decision making* and ensure small units remain able to operate independently, following the intent of their commanders rather than micromanaged.
- Future deployable force structures need to use a small enough fraction of the total force to provide *appropriate training opportunities*.

7. Conclusion and Further Work

This initial report provides a brief synopsis of the work undertaken to scope the plausible impacts of key emerging technologies on the force structures of the Australian Army in the 2020 to 2040 time frame. It focuses very tightly on the impacts on *force structure* rather than examining other issues such as force effectiveness. The most important contribution is the building of a theoretical framework based on considering the effects of potential key technological changes in each of eleven Army functions that the future land force will require to successfully achieve their mission objectives. This is worked in with an analysis of how potential key technological developments in each of these functions relates to possible functional groupings within the Australian Army.

It is particularly important to remember that this is an initial report concentrating on the plausible force structure impacts of potential key technological advances which was conducted in a short time frame with limited resources, for a specific request. It is only part of a balanced approach to considering the plausible force structure impacts of potential key technological advances and needs to be read in concert with more predictive and more secret work being undertaken by other agencies. As an initial report based on roughly thirty staff days of rushed and intensive work in response to an urgent request it catches only some of the nuances of the situation. Procurement programs and changes in force structure, training and doctrine take many years to be implemented and knowledge of the present intentions of potential adversaries could give picture of likely opposition forces in 2020. For this reason, predictive work based on known intentions is more reliable in the 2020 timeframe than this broad analysis of the potential technological developments from current research ideas. The approach used in this report is likely to be more useful in the 2040 timeframe where prediction of the exact products on the market is impossible. Neither technique will capture truly revolutionary technological breakthroughs because if we knew what these would be then they would not be called revolutionary.

The degree to which potential key technological advances impinge on the future force structure varies greatly between the eleven functional areas. This is not to say that technological advances in the more sparsely addressed areas will not have strong impacts on future force effectiveness, just that they do not appear to have much effect on future *force structure*. It may also be, as in the case of the Adaptive Campaigning functions, that the technological impact on force structure is unquantifiable as the actual structure of the Army forces in undertaking these roles was not well developed at the time of the study.

This work could obviously be extended and improved by gathering thoughtful recommendations from appropriate experts on what the technological threats and opportunities and the military weaknesses and strengths are likely to be. That would be to conduct a full and proper technology assessment followed by the expert driven TOWS analysis. Any such work must keep in focus that the most common failing of TOWS is the development of a plethora of items (often of low voracity or importance) in each of the dimensions and strive to keep the numbers of items low and their quality and relevancy high. It may be that different groups of experts are required for the technological and military dimensions or be needed for each of the eleven functions or both. Group decision making techniques like the nominal group [30] and Delphi [7] methods are techniques that can keep numbers of items low, represent diversity and keep the quality and relevance high. Delphi has the added bonus of being distributed (so the experts do not need to gather physically) and anonymous (which is particularly important to get good results from dominance hierarchies like the military or military research organisations).

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Appendix A: Additional Information on Future Technology Impact on Army Functions

A.1. Additional Information on Future Technologies and Engagement

A.1.1 Reduced Cognitive Load and Greater Situational Awareness

There is much speculation over autonomous or semi-autonomous robotic fighting vehicles replacing manned fighting vehicles. However, much the same robotics technologies that allow automated driving also allow assisted driving when coupled with credible improvements in human factors and integration technologies. Lower cognitive load from driving leaves space for other cognitive processes. In an extreme case this may mean that the roles of the driver and the vehicle commander may be able to be compressed into one person (although utmost care would need to be taken in doing so). More conceivably, the situational awareness of each vehicle may be increased sufficiently to lessen the need for overwatch (from human roles) enough that a reduction in the number of vehicles in each unit becomes possible.

A.1.2 Autonomous Robotic Engagement

Samsungs Intelligent Surveillance & Guard Robot is a stationary autonomous fighting robot with the capacity to kill people. It is already being fielded in the demilitarised zone between North and South Korea and the ethical implications of this technology are discussed under the ethical considerations section later. While many commentators seem sure that the formidable artificial intelligence problems that need to be overcome, to enable robots to tell opposition forces, own forces and civilians apart and determine when opponents are attempting to surrender, will be easily solved, the authors believe that this is unlikely to be done to a level acceptable to the Australian Government by 2040. Mobile autonomous robotic weapon platforms are, therefore, more likely to effect the force structure by their use by enemies than through their use by the Australian Army. They are also most likely to be met in highly limited contexts. One such class of weapon may be mobile mines that use a hardware based pattern matcher to identify targets and then move towards and attack them.

A.1.3 Semi-Autonomous Robotic Engagement

It is entirely conceivable that semi-autonomous robotic fighting vehicles will be available, legal and ethically acceptable in the 2020 to 2040 timeframe. Such semi-autonomous robotic fighting vehicles may start as semi-autonomous robotic reconnaissance vehicles and become armed as their operators push for armaments to assist them drawing fire and for engaging targets of opportunity or they may be planned from the start.

By 2020 all soldiers under 30 will have grown up in an environment pervaded by first person shooter games with interfaces similar to those likely for semi-autonomous robotic fighting vehicles. The degree of autonomy may vary from the ground based air defence system approach, where the operator has a big red ‘fire’ button that must be pushed to allow proposed engagements to proceed, to a situation where the semi-autonomous robotic fighting vehicle facilitates the virtual presence of the soldier on the battlefield. Coupling of integration and information presentation technologies with communications, artificial intelligence and robotics may plausibly lead to a situation by 2040 where soldiers controlling semi-autonomous robots are able to 'look down' on the battle space and effectively control many uninhabited robotic vehicles. Simpler screen based systems are even more plausible and may still allow a single human operator to exercise positive control over multiple semi-autonomous fighting robots thus multiply the firepower, presence and footprint of each operator. In either case such vehicles could massively increase the capabilities of front line soldiers, allowing them the protection of a vehicle and yet giving capabilities similar to infantry.

Another effect on force structures of semi-autonomous robotic fighting vehicles is likely to be that their destruction or disablement bears little similarity to the death or wounding of a soldier. Semi-autonomous robots do not need to be rushed to medical care and can be replaced by a spare immediately.

Use of semi-autonomous fighting robots is likely to place a premium on the human targeting operators and the communications links between the robots and their operators. A force structure implication of this is a greater potential requirement for forward based electronic warfare assets to identify the positions of enemy controllers and cut enemy communications, while protecting Australian controllers and their communications links. Another force structure implication is that command assets are likely to become even more important to target and protect.

A.1.4 Precision Weapons

It appears reasonable to assume that precision weapons will become relatively less expensive, more accurate, more responsive and have terminal effects that are more tailorable. A number of land, air and sea platforms already provide precision weapon availability for joint land warfare and the variety of platforms providing precision indirect fires is more likely to increase than to stay the same. Traditionally, forward controllers for artillery have been separate from forward air controllers. There has been movement towards collapsing of these roles. To maximise the flexibility and robustness of the small teams likely to be involved in engagements the future force structure needs to use unified calls for fire so that a single member of the team can call for indirect fires from all platforms. This means that it is more likely that fires will be available from some platform when they are needed and frees up personnel for other roles in the combat team.

Small teams employing minimum mass tactics are likely to remain the main agent through which engagement by indirect fire precision weapons is mediated. However, it would be imprudent to assume that these teams will always be in contact with the rest of the force and always be able to rely on indirect fires to save them [21]. Therefore, any future force structure needs to build small teams with sufficient organic combined arms capacity to survive on the battlefield [21].

A.1.5 Penetration

As a propellant, gunpowder has its limitations. It is difficult to push the muzzle velocity of guns using gunpowder as a propellant much over 1,200 m/s. To achieve penetration of increasingly sophisticated armour, engagement systems have had to work around this. Throughout the 20th century there were three penetration trends:

1. Total momentum delivered to the target was increased through increasing the mass of the shell either through making it larger (increasing the calibre of the gun), increasing the density of the material (e.g. using tungsten-carbide or depleted uranium in place of steel) and use of sabots (which pushed achievable muzzle velocity to around 1,800 m/s) [31, 32].
2. Momentum density on target was increased by using longer munitions (the move from spin to fin stabilised long rod penetrators was because the latter have a maximum stable length that is roughly four times as great as the former).
3. Gun momentum was ignored and penetration was made by the use of larger or more channelled explosive power: squash head devices to create spalling; shaped charges to direct the explosive power into a 'warm solid' slug of metal; and explosively formed projectiles.

Without a paradigm shift in the technologies used the main area for penetration improvement is in increasing calibre (see Figure 3).

Figure 3 In 1983 fear of new soviet tanks led Germany, the Netherlands and Switzerland to commence experimentation which led, by the early 1990's, to this concept demonstrator of a 140mm gun on the Leopard 2 (top). At the time, rumours abounded about 135mm or 152mm (bottom) Soviet tanks … but there were only ever drawings of what the West thought the Soviets may have.

Rail guns are one possible method of increasing the penetrative power of direct fire weapons. They require a power supply capable of delivering a massive current over a short time; a pair of rails able to conduct that current (and not melt due to resistive heating or armature friction or separate due to massive magnetic forces) and a conductive armature able to link the rails (and not heat weld to them). A massive current is needed to keep the rails short enough to make rail guns practical and this current runs along the positive rail, through the armature and then along the negative rail. This electric flow creates intense magnetic fields and the force from these accelerates the armature, which doubles as a sabot for the projectile, along the rails. When the armature/sabot and its projectile leave the rail gun the sabot separates and the projectile flies towards its target. A benefit of this approach is that the projectile is typically non-magnetic and non-conductive thus making it able to easily penetrate any future electric armour system. It seems plausible that, by 2040, it will be possible to overcome the problems for rail guns including:

- Capacitor size;
- Power supply and size ;
- Rails and armatures able to cope with the resistive and frictional heating generated by firing; and
- Rails bound strongly enough to withstand forces in the order of 10^7 Joules.

For reasons of rail cooling and reinforcement, it is more plausible that initial military versions will have fixed hull mounted guns and resemble assault guns or tank destroyers more than tanks. In December 2010, the US Navy successfully fired their rail gun concept (Figure 4) showing it's capability. Already the estimates for deployable versions are in 10 years time for US Navy vessels [33].

Figure 4 The US Navy Electromagnetic Cannon (rail gun) successfully test fired in December 2010[33].

A.2. Additional Information on Future Technologies and Information Collection

A.2.1 People as Information Collectors

Between now and 2040 people are likely to remain vitally important information collectors on the battlefield. How important they are relative to other sources of information will depend on the type of mission being undertaken and the exact details of the scenario faced. People will be more important in the most likely threat situation (intervention against asymmetric opponents in a failed or failing state) than in the most dangerous threat situation (combat against a peer force). This is because opponents are more likely to attempt to drop below the discrimination threshold by hiding amongst, and even pretending to be, civilians in the former than in the latter. However, simply talking to people can reveal important information no matter what the scenario faced.

There are many plausible technological advances that will help soldiers improve as information collectors. As talking to people is an especially important way of collecting information one of the advances that could be particularly helpful would be practical speech-to-speech translation. The technical challenges involved in developing this make it imprudent to construct force structures around its assumed presence. In 1964 an expert panel thought that automated language translation would be available between 1968 and 1976 [34]. Throughout the 1980's it was thought that text-to-text translation was just around the corner as was speech-to-text. Both of these have taken much longer than expected to eventuate and are still rather unreliable even when applied to languages or language pairs that a great deal of effort has been expended on. Importantly, many of these advances are limited to languages spoken by many millions of people in economically prosperous and technically advanced nations. There are few translation tools for the languages of small and economically marginalised groups that the future force is likely to need to talk with in future stability operations and their development seems unlikely even if the problems are solved for more profitable languages. None of the approaches to speech-to-speech translation presently receiving major funding goes directly from speech to speech but rather they go from speech to text to text to speech. Only the last step has been reliably implemented but even here the emotional prosody of the original speech is lost. Where text-to-text translation technologies have helped most has been in augmenting the language skills of people rather than by replacing the need for them. Automated translators can provide low quality glosses that help determine whether to proceed further, on-line dictionaries and translation memories help translators deal with less common terms and difficult grammar forms. Technological advances also make it easier to train people in linguistic skills and advances like telepresence are likely to make training able to be delivered in a more distributed manner. In short, for the future force to be able to speak to local people it will still need translators built or incorporated into its force structure.

A.2.2 Micro-robotics

It is entirely plausible that further miniaturisation of IT hardware, sensors, communications devices, power sources and mechanical devices may lead to a proliferation of micro-robotic machines on the future battlefield. It seems implausible that these will overcome the technical difficulties needed to make them weapons of engagement able to target and attack only opponents (e.g. flying down people throats to choke them; injecting toxins into people; etc.) and it also seems likely that ethical considerations may prevent their use even if it becomes technically feasible. However, there are lower barriers to overcome to make them important elements of the information collection arsenal. The very diminutiveness of micro-robotic devices, whether micro-uninhabited aerial vehicles or micro-unattended ground vehicles, is likely to limit them in many ways. They are unlikely to be able to travel far from their launch point or transmit far. Their sensors are also likely to be limited by size. The force structure effects are likely to be limited, although the force effectiveness outcomes of being able to see what is on the other side of that door without needing to kick it in could be considerable.

A.3. Additional Information on Future Technologies and Sustainment

A.3.1 Robot Assisted Driving

The general media has a strong concentration on the effects on future warfare of autonomous or semi-autonomous robotic combat vehicles but logistics vehicles of this type are much more plausible in the 2020 to 2040 timeframe. The Multi-Operated All-Terrain Vehicle by BAE systems [35], shown in Figure 5, has been developed for such a role for sustainment of troops. Driving a truck in a convoy from a depot to a designated position is a much less complicated problem than driving a fighting vehicle in such a way as to minimise the chances of that fighting vehicle being destroyed and yet maximise the opportunities of that fighting vehicle effectively engaging the enemy. Even a mother duck and ducklings arrangement where one of the trucks in a convoy is driven by a person and the others robotically will free up many people for other tasks. Unless vehicle reliability improves remarkably, these trucks will still need people to carry out basic maintenance on them. There are multiple possible effects on force structure. Logistics personnel may have their traditional roles broadened to include the protection of logistics. For example, those who would be driving trucks instead protect them and repair them when they suffer minor breakdowns. Alternately, repair units may need to develop small, low skilled formations to attach to convoys to perform the simple maintenance presently performed by truck drivers.

Figure 5 BAE systems Multi-Operated All-Terrain Vehicle has been developed to remotely supply and support troops in the field [35].

A.3.2 Rotables

Rotables are modular parts of equipment that can be exchanged in the field rather than being repaired or serviced in the field. Modern supply chain systems have made increasing use of rotables for two main reasons. The first is that the complexity of technology has, in many cases, increased beyond the capacity of maintenance and repair personnel to economically maintain or fix. Thus replacement by another module from the factory is the only option. The second is that globalisation of the manufacture and repair of goods has made it uneconomical to use highly-paid highly-skilled maintenance and repair personnel in developed nations to do jobs that can be done by a combination of:

- Less well paid low-skilled couriers from developed nations; and either
- Low-paid highly-skilled maintenance and repair personnel in developing nations; or
- Very-low-paid low-skilled production line workers in developing nations.

As vehicle technology becomes increasingly complex, as it will, it is highly plausible that the use of rotables will become increasingly attractive.

The changes to force structure that increasing use of rotables are already underway. Supply chain management has become more important and is likely to continue to do so. It will become increasingly possible and monetarily attractive to increase logistics capacity to move rotables to replace the capacity to maintain and repair equipment in the field. This offers the opportunity for a much more monetarily efficient force structure. However it also proffers the dangers of making the force brittle and highly reliant on open supply routes and increase volumes of supplies required. It is plausible that the balance of required CSS will shift more towards logistics and away from the ability to field skilled maintenance and repair units. This may make elements of the force structure look increasingly Soviet where poorly skilled conscripts sent components back to factories using a highly staffed (and mostly rail based) civilian logistics system. Of course, this model did not work well in client nations where the logistics tail was much longer due to the need to move the parts back to the USSR and the skills of and resources available to the logisticians were less.

A.3.3 Diagnostic Systems

Modern vehicle engines (and many other appliances) contain sophisticated diagnostic systems that enable maintenance personnel with appropriate computer interfaces to rapidly diagnose problems. This has been a response to the increasing complexity of vehicle engines. When coupled with an increasing use of rotables this has led to the de-skilling of the workforce in the face of greater complexity. The diagnostic system aids diagnosis more than the increase in difficulty due to changes in engine technology.

Advances in computer software and hardware along with better interfaces between people and computers and greater experience with designing diagnostic systems make it very plausible that sophisticated diagnostic systems allowing low skilled personnel to diagnose equipment problems will be almost universal by 2040. Design is also likely to become more modular so that the failing systems can be removed and replaced by spares rather than repaired.

The de-skilling and reliance on others to diagnostic system advances, is likely to have several force structure effects. As the skill needed to get broken vehicles working is likely to be reduced it is plausible that force structures will need less dedicated maintenance units. It contributes to the capacity of smaller vehicle crews to maintain their vehicles and so adds to the plausibility of vehicle crews being smaller. It also makes it more possible to build a force structure that offers low costs in peacetime but is excessively reliant on factory maintenance and vulnerable to interdiction of logistics supply lines.

A.3.4 Electric Drives

Electric drive technologies are likely to become less expensive and more reliable and could, plausibly, be introduced into military vehicles in the 2020 to 2040 timeframe. The inherent modularity of electric drives fits well with present military logistics systems that attempt to maximise the number of repairable items that are also rotable. The additional implication is that there will be a significant reduction in fuel logistics requirements which will allow those personnel to be retrained in these new areas.

A.3.5 Supply Chain Management

There is a considerable commercial imperative to improve stock control and tracking systems and it is plausible that technology will progress markedly in these areas. The use of software, inexpensive microchips, scanners and information networks to keep track of items in the supply chain will improve the reliability and tailorability of supply systems and reduce wastage and loss in storage. Automated schedulers using complex algorithms running in sophisticated software on high speed computers are likely to augment human schedulers and improve the efficiency of deliveries. The force structure impact is likely to be a reduced need for personnel in logistics, particularly in stocktaking, dispatching and scheduling roles.

A.3.6 Point of Care Testing

Various biotechnologies are deskilling point of care testing while making it more accurate and less expensive. Some examples are shown in Figure 6 where jobs previously done by skilled laboratory technicians can be done by anyone able to prick a finger and place a drop of blood on a stick. This trend is likely to continue. When coupled with improving information systems making medical records available everywhere, decision support software and simpler treatment administration mechanisms it is plausible that a higher quality of care will be available from less skilled individuals.

Figure 6 Diagnostic biochips are already on the market. Shown above are tests for Hepatitis B (far left); Dengue Fever (centre left); Malaria (centre right); and HIV 1 & 2 (far right). All produce highly accurate results in under 20 minutes.

A.3.7 Robot Assisted Medical Evacuation

Modern trauma treatment is very good and is likely to improve. The most critical element in whether wounded soldiers survive is the time that they take to reach an adequate level of medical care. Medical evacuation is carried out by skilled paramedics borne by helicopters and ground vehicles. There are already autonomous robotic land vehicles and gyrocopters and Unmanned Aerial Vehicles that are being developed for medical evacuation. Considerably more progress has been made on replacing the pilot or driver than on supplanting paramedics [36] (as shown in Figure 7). Even so, it is plausible that evacuation pods will be available in the 2020 to 2040 timeframe that provide a lower cost solution than helicopter based evacuation. It is likely that these will also provide a lower quality solution but, as timeliness has a quality all of its own, may allow better overall outcomes. The force structure implications are that someone will need to operate, service and dispatch these pods and that transport helicopters will be freed from much or all of their casualty evacuation duties and be more available for transport of other kinds.

Figure 7 Robotic Evacuation & Extraction Vehicles being developed for the US Army Medical Robotics Research through the Army's SBIR (Small Business Innovation Research) Program [36].

A.3.8 Threats

Destroying the effectiveness of a force by attacking its ability to sustain itself is a tactic that has existed for as long as there has been warfare. While the morality[9] and effectiveness of these techniques has varied, it is an enduring feature of war that opponents will seek to interdict lines of supply and carry out other actions designed to prevent forces from sustaining themselves. Several technological advances such as improvements in sensor, integration and precision guided munitions technologies are likely to make the established methods of striking at sustainment easier. The possibility of technological advances in robotics, pattern matching and nanotechnology raises the spectre of low cost autonomous or semi-autonomous vehicles attacking rear echelon forces. Protection of sustainment assets is likely to become more important and more difficult over the coming thirty-two years.

A.4. Additional Information on Future Technologies and Communication

A.4.1 Communications with Robotic Vehicles

[9] Many highly immoral actions have been militarily effective at striking at sustainment. One example is Marlborough's campaign in Bavaria in 1704 where he struck at the ability of the Elector of Bavaria to sustain his troops in the short term by physically devastating Bavaria and in the longer term by killing as many Bavarian civilians as his troops could find [27, p.84].

Communications between operators and semi-autonomous vehicles are likely to become considerably more important in the 2020 to 2040 timeframe than they are presently. Whether a force structure including semi-autonomous robotic fighting vehicles is feasible is largely dependent on the security and reliability of communications.

A.4.2 Improved Small Unit Communications

Intra-section radio communications are already technically feasible and are fielded by many armies. Advances in wireless telecommunications technologies are likely to make such systems more robust to environmental effects such as urban multipath. This is likely to cause a further emptying of the battlespace as section members can reliably and securely communicate with each other while out of sight.

A.4.3 IFF

IFF transponders are an important part of communication for the Air Force. Information technology, battery, microelectronics and security advances may plausibly reduce their cost, weight, power draw and detectable signature sufficiently to make them available to individuals. This would contribute to further emptying of the battlespace as individual soldiers will have more secure fratricide prevention measures. However the future ability to log others in the battlespace, such as neutrals and other organisations is unknown.

A.4.4 Encryption and Decryption

Barring a technological revolution in computing that somehow changes the nature of computing power, future advances in computer power are likely to continue the state where it is easier to encrypt than it is to decrypt. This means that encryption of communications is likely to remain unbreakable in real time. Quantum computing seeks such a revolution through the capacity to follow all possible solution paths at the same time. The future land force is likely to experience a finite period between own forces receiving communications and opposing forces being able to decrypt them and vice versa. This means that it will still be possible to surprise and be surprised by the enemy. Therefore force structures need to be robust enough to remain resilient in the face of the unexpected. Brittle units without sufficient organic engagement capacity to defend themselves from plausible risks (and these vary based on distance from the front, whether there is a front at all and opponent capacities) should be eschewed.

A.4.5 Telemedicine

It is plausible that telemedicine will develop to the level that diverse and highly specifically skilled medical experts (surgeons, anaesthetists, dentists, psychologists, etc.) will operate from out of the theatre of combat with only generalists in the force structure within the combat theatre. Already, medical specialists are mostly drawn from the reserve forces. The lack of requirement to even be present in the combat theatre may make it possible to contract in civilians to perform this role. Given the long standing power of the various colleges representing medical practitioners and their success at reducing the numbers of medical practitioners in training well below the numbers needed to meet demand it is likely that there will be a continuing undersupply in the general community. Telemedicine may, therefore, make it possible to outsource specialist medical care to lower wage nations with high standards thus improving care, reducing cost and, through use of professionals in different time zones, making sure that there are always specialists available. Focusing on the technology itself and its force structure implications this would mean that deployed medical units in future force structures may consist mostly of highly skilled nurses and professionals dedicated to maintaining the telemedicine system and performing immediate care.

A.4.6 Telepresence

Many highly skilled specialists are required in theatre even though they are only used occasionally. Others are used continuously in one theatre of deployment even though their optimal use would be to spread their time across multiple, geographically separate, theatres. It is entirely plausible that telepresence technologies will become sufficiently advanced by 2040 to allow telecommuting of specialists. This is particularly the case for people involved in planning and design functions such as certain headquarters staff and draughtsmen. This may allow a more efficient usage of the skills of these people. It may be done to make the deployed force more slimline and reduce its logistical needs by keeping more non-combat personnel at home. This could help with retention issues to keep older personnel with families at home with them. It may also allow more cost effective usage of civilian contractors to fill some of these skilled rolls. Whatever the reason, it is plausible that telepresence technologies will offer many opportunities to do this. A force structure effect may be to allow semi-permanent Australian based headquarters support units to be formed that will operate more efficiently than those hastily formed to deploy, because they have developed long term relationships. The main force structure effect would be to alter the deployable elements of forces by keeping more of the non-combat specialists in Australian bases.

A.4.7 Ad-hoc Networks

Ad-hoc communications networks have advanced significantly since the first packet radio networks (sponsored by DARPA[10]) of the 1970's. Present ad-hoc wireless network protocols, such as Bluetooth or Wi-Fi, allow devices to communicate without the establishment of physical links between them[11]. In the civil arena there is considerable research into wireless ad-hoc vehicular networking. When coupled with positioning systems and appropriate controllers these networks will allow vehicles to avoid collisions with each other and when coupled with roadside devices they allow automated payment of tolls and parking fees and may allow vehicles to be constrained in speed and motion so as not to run off roads or go through intersections inappropriately; to allow better traffic flow through automated control and, when coupled with navigation equipment, give drivers situational awareness of traffic conditions ahead on their route. Economic drivers are likely to lead to considerable civil funding for ad-hoc networking research. The

[10] DARPA – the US Defence Advanced Research Projects Agency
[11] Trivial examples are the linking of laptop or hand-held computers to the internet, connections between telephone headsets or handsets and their receiver/transmitters and wireless computer mice.

military applications are obvious as they provide the potential for a communications network that it robust to the destruction of major communication nodes. The ad-hoc and moving nature of the network mean that the importance of particular nodes is transitory anyway. As rapid re-routing is necessary to cope with moving nodes, rapid re-routing is possible upon the destruction of nodes. The use of wireless ad-hoc networking without communications support to fill the gaps between vehicles is unlikely, as it would lead to communications network topology becoming another constraint on the movement of combat vehicles. This communications support may be in the form of traditional communications networks but it may also be in the form of autonomous vehicles that manoeuvre to fill the network gaps. Important issues for force structure are that ad-hoc communications is likely to produce a much flatter communications structure with features that mitigate traditional signals intelligence methods. Much of the hierarchical structure of militaries is related to efficient flow of orders and information under the communication environment they have developed and operated within. Plausible advances in ad-hoc networking offer the possibility that units from different commands working next to each other will be able to communicate with each other as well as units within the same command. These networks will also mean that high rates of transmissions may no longer be able to be used to identify command or communications units as all units will transmit and all units will vary in their degree of transmission depending on the vagaries of the network topology at that moment rather than depending on their importance in a command sense.

Ad-hoc networks may make command units less identifiable and therefore more survivable on the future battlefield. Oddly, they may make command redundancy less necessary (by making command units less likely to be destroyed) while making it happen by default as small units become able to by-pass their commanders to work together.

The primary plausible force structure effect is a reduction in the number of soldiers specifically dedicated to communications needed to maintain present levels of connectivity as this role is distributed throughout the force.

A.5. Additional Information on Future Technologies and Protection

A.5.1 Vehicle Armour

The quality of the materials used in armour is likely to improve over the next thirty-two years [37]. These improvements may make it safer to be behind armour but they are unlikely to be significant enough to effect force structures. Metal, ceramic and composite armours are likely to remain heavy and bulky. Even techniques like gradient materials with a hard ceramic face seamlessly integrated with a metallic back to reduce tensile stresses from hits [38] are unlikely to offer force structure altering changes in protection. Automation of vehicle functions and superior presentation of situational awareness information may allow smaller vehicle crews (as automated driving assistance allows the driver and commander functions to be compressed into a single person) who sit within armoured hulls rather than in turrets thus leading to less area to protect. It is in alternative protection systems that force structure altering advances are likely to come.

The most visible protection alternatives to armour have been the attempts to defeat shaped charge warheads through enforcing standoff distance, deploying Explosive Reactive Armour and developing APS. Tandem charge warheads that use a small charge to destroy once-only protection systems and a larger following charge to penetrate the armour and self forging projectiles that work at stand-off ranges have been the response to these developments. Technological advances are likely to concentrate on multi-hit-capacity systems.

There are unlikely to be major technology developments in the field of armour that enforces a standoff distance between the main hull and the point at which the shaped charge is detonated. The balance between firepower and protection will remain extant.

APS seek to defeat anti armour weapons known as low-velocity self forging projectiles (also known as explosively formed penetrators or self forging fragments and shaped charge warheads using a radar directed launcher that intercepts them with a spread of pellets. Their use was pioneered by the Soviets with *thrush* (Дрожд) which saved vehicles roughly 70% of the time but produced considerable levels of fratricide amongst nearby infantry. More recent systems like *Arena* (Арена) and *Trophy/wind-coat* (חור ליעמ) have a narrower arc of engagement thus limiting infantry risk but are dangerous to close dismounted infantry. These systems are likely to improve through to 2040 and may become integrated with automatic cannon based engagement systems as part of a tiered defence. There is a high probability that they will be increasingly fielded by potential opponents and allies. Shotgun type systems will retain their inherent problem of infantry fratricide and civilian casualties, and are thus unlikely to become acceptable to the Australian Army. Radar directed grenade launcher based APS, like Diehl's AWiSS, represent a compromise between shotgun style APS and engagement using the vehicles main weapon. Overall, APS are likely to make organic infantry weapons and anti-armour missiles less effective at engaging light armoured vehicles. This will result in an increased reliance on other arms for engaging enemy light armour.

Static ground based air defence systems like Skyshield [39] are in use to destroy rocket, artillery and mortar rounds in the air. Potential future cost reductions in sensor technologies may make it practical to deploy gun based air defence systems as dual purpose anti-light-armour and anti-aircraft systems on fighting vehicles [39]. This would enable the low cost engagement of low cost automated or semi-automated robotic flying and ground vehicles as well as some (inherently inexpensive) unguided and inexpensive guided weapons. The likely weight of these potential systems and their sensors means that they will almost certainly be vehicle mounted. The force structure effect of such technology would be to move some or all of the responsibility for ground based air defence from dedicated air defence units to mechanised infantry and to make infantry more reliant on vehicles for protection against "Unmanned Ground Vehicles" and unmanned aerial vehicles.

Traditionally armour has meant heavy materials but there have been moves towards the fielding of electric armour systems [40, 41]. One type of experimental electric armour uses a conductor layer sandwiched between and insulated from two conventional armour layers, the outer one of which is earthed. 'Warm solid' slugs from shaped charges and explosively formed projectiles are all metallic due to the malleability requirements inherent in their formation. Present long rod penetrators are also metallic. As conducting rounds close the circuit between the outer armour layer and the conductor layer they experience considerable instantaneous heating and, if the system works well enough, evaporate. The alternative type of electric armour uses a capacitor sandwiched between two layers of conventional armour where the circuit is completed by the penetrator connecting the two capacitor plates. Electric armour offers an order of magnitude weight saving for a similar level of protection against shaped charges without the dangerous fragmentation associated with explosive reactive armour or an APS. The two niches that seem most likely to be filled by electric armour are improved protection from top attack munitions and lower weight side protection. Organic infantry anti-armour weapons and off-route mines (including off-route IEDs) rely on shaped charges or explosively forged projectiles for their penetrative power and so cannot be made non-conducting. Electric armour systems are likely to achieve synergies with electric drive technologies as both armour and motors can utilise electricity from the same source. The force structure effects of electric armour are likely to arise from light armoured vehicles being more survivable to assaults using organic infantry weapons and all armoured vehicles becoming less vulnerable to top attack munitions. It is also a light weight armour technology that may increase the survivability of B-vehicles (especially electric drive B-vehicles) in a complex battlefield with no front lines and thus reduce requirements on the force structure to protect these vehicles.

It is plausible that light armour protection will overmatch shaped charge or explosively formed projectile based systems such as organic infantry anti-armour weapons, off route mines and top attack munitions due to technological advances through to 2040. A conceivable effect on force structure is that infantry may become more reliant on support from armoured fighting vehicles and indirect fire weapons when engaging an enemy possessing light armour.

A.5.2 Personal Armour

Personal protective armour is likely to continue to advance and may even provide complete torso protection from personal firearms. It seems unlikely that it will be coupled with exoskeleton technology to enable more armour to be carried due to the power supply needs. Therefore crew serviced and vehicle mounted weapons systems are likely to continue to overmatch infantry armour because people will remain unable to carry a sufficient weight of armour to defeat a 0.50 calibre round. Protection from shell splinters and debris is likely to be even more substantial than it is now and this may lead to blast overpressure damage from precision guided explosive munitions becoming the primary indirect fire threat to the lives of infantry soldiers. So infantry may become more able to survive indirect fire weapons and individual weapons whilst still needing further protection from crew serviced direct fire weapons. Technological advances may reduce mortality rates and the severity (and possibly even number) of injuries but are unlikely to effect force structure.

A.5.3 Avoiding Detection

The detectability or otherwise of opponents on the future battlefield is one of the fundamental questions for future force structure. Whether forces on the field rise above the discrimination threshold is at the heart of the question of whether protection will overmatch engagement. The most common method of protection against destruction through engagement is to avoid detection and thereby avoid the engagement. There are many plausible key technological advances in the areas of sensors and integration that increase the chances of detection. However, there are also protection technologies from the fields of electronic warfare and continuing realities such as cover and the capacity to retreat into complex physical and human terrain that are countervailing forces.

It is plausible that protection provided by remaining unseen through use of camouflage or obscurants will be invalidated by sensors that are more capable, more integrated and less expensive (and therefore more common). It is believable that even advanced obscurant technologies like spectral smoke will be defeated by improved sensor integration. Thus providing a broader spectrum to the searcher and better communication technologies allows multiple perspectives to be integrated. They will also allow an ability to close with the enemy.

Cover is another important form of protection from detection which has the added benefit of making direct fire engagement impossible. Forces may retreat into more complex physical terrain to gain better cover but they can also make the terrain they are in more physically complex through their own actions. The use of precision weapons and capable, integrated sensors by U.S. led coalition forces against Iraq in 1991 and 2003 have been used as examples of how engineering works are unable to make the battlefield sufficiently complex for a less technologically capable force to stand against a more technologically advanced one. However, these uses of advanced sensor systems and precision guided weapons have been used by technologically sophisticated and highly skilled forces against technologically unsophisticated and poorly skilled forces. Similar differentials in skill levels in the past have not produced such one sided outcomes [19] but this does not mean that it is only the sensor, integration and precision weapon technologies that have produced such overwhelming mismatches. Technology and skill level may interact in a non-linear manner [19] meaning that advanced detection and engagement technologies greatly accentuate the differences in outcomes that arise from different skill levels. This is important as the capacity to use highly capable and integrated sensors might not help much against a skilled opponent that can detect, engage and destroy or drive off those sensors or spoof or jam them.

Detection and engagement technologies are likely to make skilful engineering support more important in future force structures. An example of the disasters that arise from poor use of force constructed cover comes from the Battle of 73 Easting [19]. Iraqi fighting vehicles were put into hull down positions by pushing sand berms around them instead of digging holes and spreading the spoil. This made the vehicles more visible rather than less visible and offered no extra protection. If good engineering support is coupled with engagement of the opponents' sensors and indirect fire weapons then well-constructed firing positions are likely to remain important to future land forces. Cover will almost certainly become harder to find or construct and forces are likely to become detectable from increasing distances but it is unlikely that a situation will develop where information does not need to be fought for.

The main force structure effect is that the ability to conduct reconnaissance by fire needs to be built into future forces as does the ability to counter, as effectively as possible, opponents seeking to conduct reconnaissance by fire of their own.

A.5.4 Electronic Warfare

In the air and at sea it has been common to use electronic warfare systems and decoys to spoof or jam the sensors directing weapons. This has also occurred on land. Second generation anti-tank missiles often had infrared beacons on their tails to allow controllers to identify their position and steer them onto target. Vehicle mounted infrared beacons were used to spoof these controllers into thinking that the missile was on target because the controller picked up the beacon on the target rather than the one on the missile. Laser decoys which redirect weapon targeting to new locations and infrared countermeasures that make an infrared signal appear to come from a third, off vehicle, location [42] are unlikely to be as useful with multi-spectrum integrated sensors. However, just as technological progress will make sensor systems less expensive and allow them to be placed on cheaper and more disposable platforms it will also make electronic warfare systems less expensive, more available and more capable. It is probable that the long duel between sensor-guidance systems and electronic warfare systems will continue into the future.

A.5.5 Mine Protection

Distance protects not only from shaped charges but also from the overpressure effects of explosions. Assuming opponents will avoid spinning detonations[12] which produce sub-optimal and unpredictable pressure fronts, this means that the Puma's ground clearance of 450 mm exposes it to up to 9% more overpressure than the base of the Bushranger's 470 mm clearance v-shaped chassis would experience from the same explosion. It is difficult to combine the low silhouette required to minimise visual detection chances and chassis exposure to direct fire attack with the high ground clearance necessary to provide optimal under-vehicle mine protection in a single vehicle. This is particularly the case because the v-shaped chassis bottom that is optimal for mine protection makes the vehicle silhouette even higher. This is a problem that technology is unlikely to be able to robustly solve through to 2040. Improvements in the direct fire weapons fielded by technologically advanced adversaries and the attractiveness of large under-vehicle mines to asymmetric adversaries may combine to make it necessary to have entirely different vehicle fleets when operating against these groups. A plausible force structure effect, in the worst case, is that the future land force may need to have alternative dispositions for every unit when facing these differing threats or may need to specialise a part of the force in asymmetric warfare and another to face a technologically advanced adversary.

[12] Spinning Detonations produce a poor overall performance of the munition in terms of overpressure generation and fragment acceleration

Mine protection methods are also likely to improve if future vehicles use electric drive trains. These allows easier placement of expendable drive motors and wheels. It minimises the need for holes in the armour and thus improves survivability. Their shedable nature makes them easier to repair. This reduces the degree of redundancy required in the vehicle fleets of future force structures to cope with a given mine threat as vehicles are less likely to be destroyed and more likely to be rapidly repaired.

A.5.6 Fratricide Prevention

An important element of protection is the prevention of fratricide. Land forces typically do this by maintaining good knowledge of own force positions and by visual identification of targets. Air forces use these methods but also use IFF transponders to help prevent fratricide. There has long been the technical capacity to fit IFF transponders on military vehicles but cost and technical effectiveness has been a limitation. Increasing cost reductions and technological breakthroughs are likely to make IFF practical for vehicles and, possibly, even for individuals in the 2020 to 2040 timeframe. The force structure effect of such a technology would be to make it less critical to know the positions of ones own forces thus allowing greater decentralisation of decision making.

A.5.7 Enforcing Standoff Distances

It is exceedingly plausible that engagement by robotic vehicles will become more common by 2040. Australian soldiers already need to be cautious of vehicle borne improvised explosive devices but are likely to need to be even more careful when moving vehicles can be driven by autonomous robots rather than fragile humans. Robotic driving could make truck bombs an even more important weapon in the arsenal of asymmetric opponents. This will make it more critical to preventing such weapon systems from closing sufficiently to destroy their target. Urban asymmetrical warfare has already led to lightweight, rapidly erectable and dismantleable engineering solutions to keep truck mounted suicide bombers away from temporary checkpoints [43]. Engineering assets will need to be included in future force structures that are able to enforce standoff distances against heavy vehicles at hastily established checkpoints.

A.5.8 Protection by Fire

Aggressively attacking attackers is an important form of protection. The objective may be to destroy, suppress, disperse or distract the attacker[13]. Already, modern anti-armour weapons do not need to be guided to their targets once launched but the objectives of destroying, suppressing or dispersing attackers are still valid. Advances in technology are likely to make it considerably easier to localise where direct fire originates from by 2040. Vehicle based detection of the rocket plume of anti-armour weapons is already possible [42] but firearm shooter localisation is not. Shooter localisation to within a one metre cube and with two second latency is already possible in complex urban terrain using static

[13] the latter is particularly the case for first and second generation anti-armour missiles which need to be controlled to their target

sound sensors [44]. Coupling of present sound sensing, software, wireless systems and positioning technology make the development of shooter localisation using wireless ad-hoc networks of vehicles, or even of individuals, extremely plausible in the 2020 to 2040 timeframe. This will have the dual force structure implications of making direct fire assets almost impossible to protect from sophisticated opponents through use of cover, camouflage or obscurants but will make it more important for assets to be able to withstand the first shot and have the capacity to respond using direct fires. It also places a higher premium on detecting without being detected and then engaging using remote indirect fire weapons so as not to reveal your position. This reinforces the need to integrate forward observers, able to call on the broadest possible range of indirect fires with infantry to give them firepower that they can use while minimising risk. It also implies an increasing security against direct engagement by infantry for light armoured vehicles; reinforces the importance of armour able to withstand organic infantry weapons; and underlines the need for direct fire engagement weapons able to destroy opponents quickly.

A.5.9 Movement

Artillery has suffered from counter-battery fire almost since its inception and the importance of mobility as a form of protection is only likely to increase. Improvements in sensors, communications, networking and integration technologies are only reduce the time between land based indirect fire assets commencing a fire mission and counter battery fire starting to fall on them. Indirect fire weapons systems that cannot rapidly move after firing cannot hope to survive on the future battlefield without massive protection of some other form. This adds to the attractiveness of self-propelled or self-propelled and armoured artillery and mortar systems in future force structures.

A.6. Additional Information on Future Technologies and Movement

A.6.1 Pharmaceuticals

Throughout the 20th century militaries across the world have, occasionally, used pharmaceuticals to keep their soldiers awake for long periods. Most of these attempts have produced soldiers who are awake but are mentally impaired in some way. The advent of ampakines like Modafinil has made it possible to keep soldiers awake and alert for long periods without serious adverse effects. Further developments may improve the ability of the future land force to conduct sustained mobility operations over the period of several days.

Amphetamines have a history of being used to prolonging the time that military personnel can operate continuously. These have had a number of adverse side effects. Many of the German paratroops dropped on Crete had been dosed with amphetamines and this was linked to several jumping without parachutes [45]. Pilots have often been dosed with amphetamines [45] to enable them to continue operating for extended times and this has occasionally led to misjudgements[14].

Modafinil was developed to allow people afflicted with narcolepsy to lead normal lives. There are now several closely related substances (other ampakines) but Modafinil is the most used and it safely allows at least two days and a night of alert wakefulness with only a single nights sleep needed to recover [46]. It was used on a large scale by French land forces during the liberation of Kuwait [45] and is currently being used by the US and UK in Afghanistan and Iraq. There is considerable research interest in other ampakines, such as CX717 so further improvements in time awake seem plausible. Mice are known to drop dead after quite short sleep deprivations and people also have some physiological limit (that we don't want to find out about) but it seems plausible that two days and a night is not the most that is possible. A force of soldiers who can stay awake and alert continuously for three days may need force structure changes to cope with their ability to undertake continuous mobility operations for this length of time. A possible effect of such whole of force manoeuvre capacity is greater strain on logistics units. It may also be necessary to provide increased engineering support for mobility if operational tempo is increased.

A.6.2 Autonomous Vehicles

The plausible prospect of automated driving systems by 2040 has some interesting mobility implications. The ability to move without the need to have a driver directly controlling the vehicle is more likely for logistics vehicles than for first line vehicles as the complexity of the environment they operate in is less. The main force structure implication of this plausible change is that equipment could move itself and the force could become more mobile with fewer drivers.

A.6.3 Power Source Mismatches

One of the potential impediments to mobility that could plausibly arise from changes in technology is that, for some period, different sources of motive power may become standards in different parts of the world. If fossil fuel replacement technologies are adopted for environmental or cost reasons there is no reason why every nation will *initially* adopt the same technologies. It is likely that one technology will emerge as being pre-eminent but there may be a period when the predominant source of motive power in civil use in Australia differs from that used in a region or regions that the future land force is operating in. This will have considerable implications for mobility as it may mean that fuel is unable to be purchased locally. The force structure implication is that the logistical stress of deploying a force will be greater and the ability of the force to move fuel long distances will need to be greater.

[14] Major Harry Schmidt and Major William Umbach, two US F-16 pilots who, while on amphetamines to keep them alert, mistakenly bombed a Canadian infantry unit in Afghanistan, killing four and injuring eight, are recent examples.

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19. ABSTRACT

This report provides the outcomes from a study which provided input to the Australian Army submission for the 2009 white paper. It is a formal documentation of the outcomes and a record of the content which was provided the client in 2008. To understand the potential key technological developments that are likely to impact on the Army After Next 2020-2040, an analysis of future technologies on Army functions was undertaken focussing on impacts to force structures. A modified TOWS (Threats, Opportunities, Weaknesses & Strengths) technique was applied to eleven Army functions across each technology area. Brief assessments are made to the possible impact of future technologies on a range of Army unit types.