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Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritisation

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ABSTRACT

Army Research and Development Request (ARDR) 16/0054 requires examination of the opportunities for employment and associated effects of autonomy and automation across Combat Service Support (CSS) functions. This report outlines the results of a scoping study, subject matter expert discussions and workshop, and use case development for automated and autonomous systems for CSS. The scoping study covers key concepts and trends, a technology scan, and identification of potential applications for logistic operations. The outcomes of the workshop with Army Headquarters personnel include prioritisation of the shortlisted technologies with the selection of the top four technologies for further research: predictive analytics, last-mile logistics unmanned aerial systems, portable networked health diagnostic technology, and semi-autonomous convoys. Further discussions identify key information requirements and delimiters for the selected technologies. The report goes on to present detailed use cases for two technologies of interest: semi-autonomous convoys and last-mile logistics unmanned aerial systems, including a use case for enhanced battle casualty care.

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Executive Summary

Technological developments in the space of automation and autonomy represent one of the most significant technological trends that affect military operations today. This report contributes to the Army Research and Development Request (ARDR) 16/0054 in examining the potential use of automated and autonomous systems in Combat Service Support (CSS). It also builds on the work conducted as part of The Technical Cooperation Program (TTCP) Land Group Technical Panel 6 concerning autonomy within supply and distribution.

The first part of this document outlines the key findings of an initial scoping study, covering the development of a conceptual model, examination of key trends, a detailed technology scan across different types of automated and autonomous systems, and mapping of these to potential applications in Land Logistics.

The conceptual model considers key aspects of the problem space. This includes the types of technologies that fall under automation and autonomy umbrella: Logistic Information Systems (LIS), various unmanned systems and swarms, human augmentation systems, power and energy management systems, and a wide range of emerging health technologies. The areas of application for these systems are mapped to the broad logistic functions in supply, transport, health, engineering and maintenance, Command and Control (C2), and capability life-cycle management. The model further considers the internal and external drivers across the social, technological, environmental, economic, political and military sectors as well the operational context for different mission types and environments.

Consideration of the key aspects serves to highlight the main challenges for automated and autonomous systems. These include data-management and security; balance of decision-making and trust; ability to deal with complex environments; technological maturity and specific physical constraints; reliance on GPS for navigation; organisational integration and human-machine interface; and lack of regulatory ecosystem. The general desired characteristics for these systems in military environment are listed as low supervisory burden, graceful degradation, low-cost, robustness, multi-functionality, modularity, and adaptability.

The technology scan highlights a large number of potential applications in logistics. Through review of military technology reports and discussions with ADF logistic officers,

this study narrows them down to specific employment concepts across the logistic functions:

- Supply and transport: advanced LIS for supply-chain optimisation, asset visibility and risk-management; unmanned systems and semi-autonomous convoys for distribution tasks; unmanned squad support systems for loads and power supply; automated materiel handling equipment (MHE); and exoskeletons as a MHE alternative.
- Engineering, maintenance and field services: Condition-Based Maintenance (CBM); use of small robots for routine maintenance; and automated construction machinery.
- Health: LIS for more responsive medical resupply; unmanned systems for casualty evacuation and for bringing surgical capability forward; use of augmented reality and telemedicine for access to specialist care; automated patient-stabilisation systems; advanced prosthetics; field sterilisation systems; automated portable diagnostic devices to replace pathology laboratories; and persistent telemetry for casualties as well as background monitoring for soldiers.
- C2 and capability life-cycle management: LIS for long-term fleet management and supply chain risk-management; and unmanned systems for situational awareness.

The second part of this report covers a workshop activity with Army logistics subject matter experts (SMEs) at Army Headquarters, conducted in order to refine further research directions. The workshop discussions covered arguments for and against the use of specific technologies, a technology prioritisation exercise, discussion of specific information requirements and discriminators for the technologies, as well as a review of selected use cases. As a result of the workshop, the large list from the scoping study was narrowed down to the top four technologies of interest for CSS:

- Predictive analytics for supply chain optimisation, logistic planning and risk management
- Last-mile logistics unmanned aerial systems (UAS) for delivery of critical material to isolated and contested areas, to dispersed units, and for enhanced battle casualty care
- Portable networked health diagnostic technology for enhanced casualty care and health planning
- Semi-autonomous convoys for distribution in semi-structured environments.

In discussing the key characteristics for selection of technologies, the main factors are highlighted as force protection, improvements to CSS delivery, system vulnerability and cost of ownership. Other considerations cover cross-domain effects, compatibility with projects and operational concepts, and user acceptance.

The report goes on to outline detailed use cases developed for the employment of UAS in distribution tasks and battle casualty management, and for semi-autonomous convoys. These use cases were developed using systems engineering principles, and refined during the SME workshop. Common issues arising from detailed examination of the use cases include establishment of a value proposition, which would consider where the use of the technology is appropriate and warranted. A significant common requirement is development of clear C2 frameworks in asset ownership and tactical/operational control. Technology considerations include communication range, cyber-security issues and integration with organisational processes. Additional issues derived from use cases are asset protection and signatures, flexibility and alternative uses in tasking, and requirement for overall legal, doctrinal and regulatory frameworks.

Recommendations for ongoing work are provided in identification and analysis of emerging technologies, establishment of a common framework for further development of technology concepts of employment, and use of scenarios. Modelling and simulation is suggested for development of robust business cases. A requirement for detailed data management and exploitation strategies for any new networked system is again emphasized.

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Contents

Acronyms

2IC	Second-In-Command
3D	Three-dimensional
A3	Automation, Autonomy and Autonomous Systems
AACUS	Autonomous Aerial Cargo/Utility System
AAI	Aircraft Armaments Inc.
ACCS	Autonomous Critical Care System
ACFR	Australian Centre for Field Robotics
ACRV	ARC Centre of Excellence for Robotic Vision
AD	Aerospace Division
ADF	Australian Defence Force
AHT	Autonomous haul trucks
AI	Artificial Intelligence
AITV	Autonomous Internally Transportable Vehicle
AM	Additive Manufacturing
AMAS	Autonomous Mobility Applique System
ANU	Australian National University
AO	Area of Operations
AR	Augmented Reality
ARC	Australian Research Council
ARDR	Army Research and Development Request
ARES	Aerial Reconfigurable Embedded System
ARES-V	Adaptive Resolution Stereo-Vision
ARIBO	Applied Robotics for Installation and Base Operations
ARL	US Army Research Laboratory
ARPI	US Autonomous Research Pilot Initiatives
ASCG	Autonomy Strategic Challenge Group
ASL	Autonomous Systems Laboratory
ASLO	Army School of Logistic Operations
ASUR	Autonomous Systems Underpinning Research
ATEAM	Allied Teams Enhanced by Autonomous Machines
AS	Australia
BEAR	Battlefield Extraction-Assist Robot
C2	Command and Control
CASEVAC	Casualty Evacuation
CAV	Cavalry
CBM	Condition Based Maintenance
CBRN	Chemical, Biological, Radiological and Nuclear
CD	Capability Demonstrations
CEWD	Cyber and Electronic Warfare Division
Comd	Command
COP	Common Operating Picture
COTS	Commercial-Off-The-Shelf
CPM	Commercial Project Management

CSIRO	Commonwealth Science and Industry Research Organisation
CSS	Combat Service Support
CSSB	Combat Service Support Battalion
DARPA	Defense Advanced Research Projects Agency
DBW	Drive by Wire
DIE	Defence Information Requirement
DoD	(US) Department of Defense
DRDC	Defence Research and Development Canada
DSAT	Dismounted Soldier Autonomy Tools
DST	Defence Science and Technology
Dstl	UK Defence Science and Technology Laboratory
DT&E	Developmental Test and Evaluation
DTRA	Defence Threat Reduction Agency
ECG	Electrocardiogram
EEG/ERP	Electroencephalogram/Effective Refractory Period
ELISA	Enzyme Linked Immunosorbent Assay
EM	Electromagnetic
ERP	Enterprise Resource Planning
EV	Electric Vehicle
FIC	Fundamental Inputs to Capability
Fmn	Formation
FSB	Force Support Battalion
FW	Fixed Wing
GCSS	Global Combat Support System
GPS	Global Positioning System
GUSS	Ground Unmanned Support Surrogate
HADR	Humanitarian Assistance/Disaster Relief
HIV	Human Immunodeficiency Virus
HMI	Human-Machine Interface
HQ	Headquarters
HULC	Human Universal Load Carrier
HUMS	Health and Usage Monitoring System
IAI	Israel Aerospace Industries
ICT	Information and Communications Technology
IED	Improvised Explosive Device
IHMC	Institute for Human Machine Cognition
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IoT	Internet of Things
IOT	In Order To
ISPDS	Integrated Soldier Power and Data System
ISR	Intelligence, Surveillance, Reconnaissance
ISTAR	Intelligence, Surveillance, Target Acquisition & Reconnaissance
ITS	Intelligent Transportation System
JCTD	Joint Capability Technology Demonstration

JOAD	Joint and Operations Analysis Division
JPADS	Joint Precision Airdrop Systems
JPL	Jet Propulsion Laboratory
KTA	Key Technology Area
LCPL	Lance Corporal
LD	Land Division
LIA	Logistics Innovation Agency
LIDAR	Light Detection And Ranging
LIS	Logistics Information Systems
LMP	Logistics Modernisation Programme
LOAC	Logistic Officer Advanced Course
LOCUST	Low-Cost UAV Swarming Technology
LogIC	Logistic Integration Capstone
LS3	Legged Squad Support System
MARTI	Mobile Autonomous Robotics Technology Initiative
MAST	Micro Autonomous Systems and Technology
MC-MACE	Monitoring and Controlling Multiple Assets in Complex Environments
MCWL	Marine Corps Warfighting Laboratory
MD	Maritime Division
MHE	Material Handling Equipment
MILIS	Military Integrated Logistic Information System
MIT	Massachusetts Institute of Technology
MMIST	Mist Mobility Integrated Technology
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NICTA	National ICT Australia
NO/MO	Nursing Officer/Medical Officer
NREL	National Renewable Energy Laboratory
NSB	National Support Base
NSID	National Security, Intelligence, Surveillance and Reconnaissance Division
NSWC	US Naval Surface Warfare Centre
NUS	National University of Singapore
ONR	US Office of Naval Research
OPSO	Operations Officer
OT&E	Operational Test and Evaluation
PCET	Platform Capabilities Emerging Technologies
PDDL	Planning Domain Definition Language
PNT	Position, Navigation and Timing
POC	Point of Contact
POW	Prisoner of War
R&D	Research and Development
RAAMC	Royal Australian Army Medical Corps
RACT	Royal Australian Corps of Transport
RAM	Reliability, Availability, Maintainability
RAR	Royal Armoured Regiment

RDECOM	US Army Research Development and Engineering Command
Recon	Reconnaissance
Replen	Replenishment
RFID	Radio Frequency Identification
RGB	Red Green Blue
ROE	Rules of Engagement
RPR	Rapid Palletising Robot
RW	Rotary Wing
S&T	Science and Technology
SAM	Semi-Automated Mason
SAP	Systems, Applications and Processing
SCE	Supply Chain Execution
SIPS	Soldier Integrated Power System
SLAM	Simultaneous Localisation and Mapping
SME	Subject Matter Expert
SMSS	Squad Mission Support System
SOP	Standard Operating Procedure
STRATUS	Strategic Mobility Support System
SUMET	Small Unit Mobility Enhancement Technology
SWaP-C	Size, Weight, Power and Cooling
SWORDS	Special Weapons Observation Reconnaissance Detection System
SwRI	Southwest Research Institute
T&E	Testing and Evaluation
TALOS	Tactical Assault Light Operator Suit
TARDEC	US Army Tank Automotive Research, Development and Engineering Center
TN	Technical Note
TORVICE	Trusted Operation of Robotic Vehicles in Contested Environments
TRL	Technology Readiness Levels
TP	Technical Panel
Tpt	Transport
TTCP	The Technical Cooperation Program
UAS/UAV	Unmanned Aerial System/Vehicle
UGS/UGV	Unmanned Ground System/Vehicle
UK	United Kingdom
UMS	Unmanned Maritime Systems
US	United States
VTOL	Vertical Take-Off and Landing
WAVE	Wide Area Virtual Environment
WngO	Warning Order

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1. Introduction

Autonomy, Automation and Autonomous Systems (A3) are developing rapidly in an environment of low barriers to innovation and globalised access to technology. Their growing presence on the battlefield is due to the advantages of endurance, consistency and expendability.

In accordance with the Army Research and Development Request (ARDR) ARM 16/0054, the aim of the work summarised in this report is to explore the problem space of using automated and autonomous systems for military logistic operations, and to elicit the specific requirements, contextual factors and potential Australian Defence Force (ADF) Land Logistics applications of such systems.

To this end, three major activities have been undertaken. An initial scoping study was completed by the authors as part of The Technical Cooperation Programme (TTCP) Land Group Technical Panel 6 (TP-6), Land Force Logistics Key Technology Area C – autonomy within supply and distribution [1]. This scoping study encompassed the development of a conceptual model, examination of key trends, a survey of national programmes related to autonomy in logistics, a detailed technology scan across different types of automated and autonomous systems, and mapping of these to potential applications in Land Logistics.

Subsequently, the authors undertook several activities to prioritise the areas of technology and applications resulting from the scoping study, and to elicit information requirements for CSS. The activities encompassed discussions with Army stakeholders and a facilitated workshop with Subject Matter Expert (SME) from Army Headquarters (HQ) to elicit the more relevant technologies for CSS and to refine further research directions. The workshop itself comprised a discussion on arguments for and against the use of specific technologies; a technology prioritisation exercise; discussion of specific information requirements and discriminators for the selection of technologies; as well as review of selected use cases. As a result of the workshop, the large list of technologies and applications from the scoping study was narrowed down to the top four of interest for CSS, together with the rationale for their selection.

Further, the context for potential use of two selected technologies ("last-mile" logistic Unmanned Aerial Systems (UAS) and semi-autonomous convoys) has been developed through three detailed use cases. These use cases were developed using systems engineering principles, and refined during the SME workshop.

This report is structured as follows. Chapter 2 provides a summary and results of the TTCP scoping study, likewise for the prioritisation activity in Chapter 3. Chapter 4 presents the detailed use cases. The report goes on to provide a discussion of the study validity and constraints in Chapter 5, and to draw conclusions and recommendations for further work in Chapter 6.

2. Scoping Automated and Autonomous Systems for Land Logistics

2.1 Key Concepts and Terminology

The emerging field of automated and autonomous systems has given rise to a number of classification systems for these technologies. Linear scales are no longer recommended by the United States Defence Science Board [2, 3]. A more comprehensive, three-dimensional scale is described in the recent North Atlantic Treaty Organization (NATO) report on autonomous systems [3].

This framework recognises that development of automated and autonomous systems doesn't move in just one direction, and that most systems can be described in terms of three key attributes:

- The human-machine command-and-control (C2) relationship
- The sophistication of the machine's decision making
- The type of decision or function being automated

The human-machine command relationship is often described using terms such as 'human in the loop', where the machine can perform a function for some time, but at certain points requires human input before continuing. 'Human on the loop' usually describes machines that can perform a function on their own, but have a human monitoring them. 'Human out of the loop' is a system that functions on its own with humans unable to intervene.

The sophistication of decision making is the parameter described by terms such as 'automatic' (simple, mechanical responses), 'automated' (complex, rule-based systems), and 'autonomous' (machines that exhibit self-direction, self-learning or emergent behaviour).

The type of decision or function being automated underpins any other discussions of a machine being 'autonomous' or 'semi-autonomous'. Fundamentally, it determines the level of complexity and risk associated with use of the machine.

This three-dimensional framework is summarised graphically in Figure 1 and demonstrated using examples of a household toaster versus a Predator UAS.

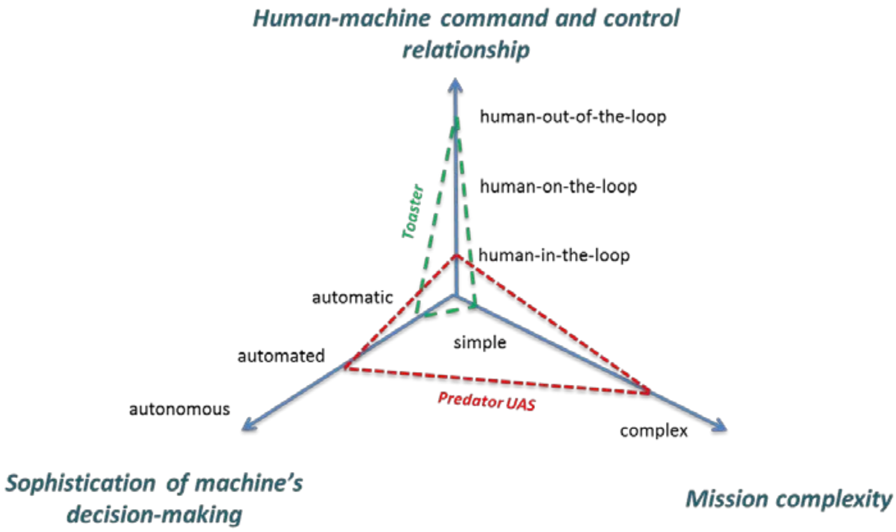

Figure 1: Three-dimensional framework for classifying automated and autonomous systems

2.2 Conceptual Model for Automated and Autonomous Systems in the Context of Land Logistics

The conceptual model developed for this problem space brings together key aspects of the technology in question, the context of its application, and the key internal and external drivers. This conceptual model is shown in Figure 2. The purpose of this conceptual model is to clarify the various dimensions and links in this problem space. It also serves as a basis for identifying further areas of threat and opportunity, and as a framework for construction of use cases in subsequent technology evaluation work. The information in the model is based on a review of [2, 4-13] and input from TP-6 members.

The logistic functions explored within the scoping study include Combat Service Support (CSS) functions, as well as wider logistic support in-garrison and throughout the capability life-cycle. However, the focus of logistic applications is on Land operations and therefore doesn't take into account joint effects, such as for amphibious operations.

2.2.1 Key Aspects of Automated and Autonomous Systems

The blue field in the model (left side in Figure 2) summarises the key aspects of this technology: the types of systems, the enabling technologies and processes, and the emerging research directions.

The types of automated and autonomous systems considered comprise:

- Logistic Information Systems (LIS)
- Unmanned Aerial Systems (UAS)/Unmanned Aerial Vehicles (UAV)
- Unmanned Ground Systems (UGS)/Unmanned Ground Vehicles (UGV)
- Unmanned Maritime Systems (UMS)

- Swarms
- Human Augmentation Systems
- Power and Energy Management Systems
- Health Systems.

Enabling technologies and processes include navigation, mission sensing (as related object and event recognition), communications and piloting, machine intelligence for planning, learning and data analysis, mobile manipulation, energy storage and management, propulsion/mobility mechanisms, human-machine interface (HMI), and multi-agent coordination [2].

The current focus of emerging research is in development of data-intensive, multi-sensor, multi-mission systems that can operate across the full range of physical environments, including space. This is supported by research projects into self-healing and self-replication, novel sensors, microplatforms, biomechanoids, nanotechnology, weaponisation and nanoenergetics, modularisation, advanced materials, neural interfaces and alternative energy sources. As the presence of automated systems on the battlefield grows, the development of countermeasures is growing commensurately.

Additionally, the overarching parameters for this technology (shown in the blue area of the model) include the level of decision-making delegation, teaming scale (humans to machines), level of machine intelligence, and physical parameters (size, payload capacity, range, robustness, signature, and mobility). Technology application is tied in with mission complexity, with the same system potentially employable in different roles.

2.2.2 Land Logistics Operations Context

Contextual aspects of Land Logistics operations relevant to technology applications are shown in the green field of the model (right side in Figure 2). These are based on the previously completed work on aspects of Land Logistics operations [9] and comprise the enduring logistic effects and the parameters that apply to logistic operations: desired operational characteristics, and types of operations. The types of operations encompass the nature of the mission, the level of hostility in the area, geographic location, physical environment, physical domain (land, air or sea), and the information domain aspects such as network availability. These aspects, in turn, influence the balance of the required logistic effects, the capacity requirements, and the key constraints and vulnerabilities for employment of automated and autonomous systems.

2.2.3 External and Internal Drivers

The yellow field (bottom of Figure 2) within the conceptual model summarises external and internal drivers in terms of social/cultural, technological, environmental, economic and political/military meta-trends. These trends can be expected to shape the level and focus of investment in development of the technology, and the degree of adoption and acceptance.

2.2.4 Current Challenges and Desired Characteristics for Military Automated and Autonomous Systems

As a derivative of the state of technology, the desired context for use and the prevailing meta-trends, the current challenges for automated and autonomous systems and the desired characteristics in the military context are summarised in the orange field (top centre of Figure 2). The current challenges are discussed in more detail in Section 2.5.

The list of the desired characteristics is drawn largely from work on technology assessment methods previously completed by the authors for ADF Land Logistics operations [9]. It is based on translation of operational requirements into technology requirements. As this is a general list of desired characteristics, particular aspects will apply to some systems to a greater extent than others.

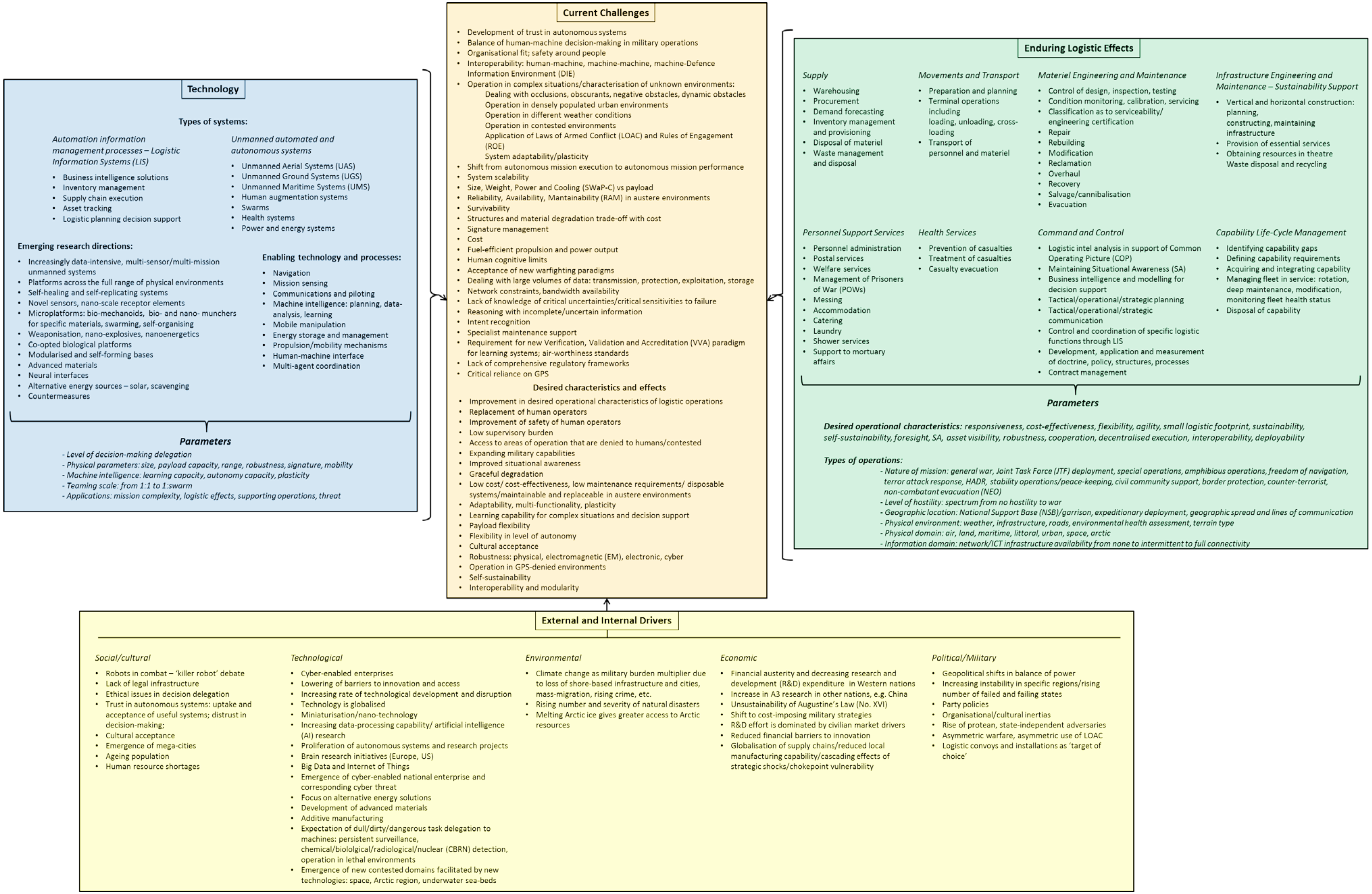

Figure 2: Conceptual model for discussion of automated and autonomous systems in the context of military Land Logistics operations

2.3 National and International Programmes in Automated and Autonomous Systems

The list of current national and international initiatives into automated and autonomous systems is provided in Appendix A. The list covers programmes from TTCP partners (Australia, United States (US), United Kingdom (UK) and Canada) with a focus on programmes that are relevant to the use of autonomy in Land Logistics operations. They range from the use of autonomous and semi-autonomous vehicles and air platforms to machine cognition and human-machine teaming. Although the list doesn't cover programmes from countries outside of TTCP, it should be kept in mind that this technology is a focus of research for most large military organisations across the world.

Research into enabling technologies such as sensors, machine intelligence, and human machine interfaces is conducted across all partner nations. Other initiatives that are relevant to logistics include:

- Programmes in Australia include exploration of autonomy-enabled concepts in logistic operations, and investigation of supporting technologies such as machine cognition and learning, human-machine interface, and novel sensors. Practical solutions for automating agricultural and mining sectors are being explored by civilian organisations and universities.
- US government programmes focus heavily on the development of UAS/UGS platforms of various sizes for a range of functions, including distribution. Autonomy kits are also being developed as an alternative to entire platform replacement.
- UK programmes encompass research into enabling technologies such as driver safety aids, and validation and verification protocols. In addition, a couple of programmes look at new concepts for nano-platforms and combination of A3 systems with advanced manufacturing technologies.
- Canadian programmes and initiatives similarly focus on new concepts for use of emerging A3 technologies in logistic operations. One of the specifically considered technologies is development of robotic follower capabilities for vehicles.
- International collaborations include investigation of new logistic concepts and testing of unmanned platforms in military scenarios.

The survey conducted for this study didn't identify specific programmes or initiatives for investigation of swarming impacts, for use of human augmentation systems, for employment of automated health systems, or for use of UMS in logistic operations.

2.4 Current State of Technology

The overall level of development in automated and autonomous system components is summarised in Table 1 based on the information provided in recent military technology reports [2, 14].

Table 1: Overall development level of automated and autonomous systems described in terms of component technology [2, 14].

Principal component	State of development
Navigation	Currently, ground systems use Global Positioning System (GPS) and active range sensors for navigation and ground obstacle avoidance and mapping (although obstacle avoidance for aerial and underwater systems remains a challenge). UGS use sensors such as Light Detection and Ranging (LIDAR), stereovision and Red, Green Blue (RGB) sensors. These can be affected by environmental effects such as changes in lighting, dust, smoke, and fog. Range sensors such as lasers are more reliable, but increase potential for detection by opposing forces. UAS have achieved some sense-and-avoid capabilities with the use of passive computer vision and active sensing. Inertial Navigation Systems (INS) are used to improve GPS positioning accuracy and assist with navigation in GPS-denied environments. Current INS systems tend to 'drift' over time, but more accurate systems with cross-checks (such as visual object recognition and optical flow technologies) are in development.
Sensing and object recognition during missions	Automated and autonomous systems are now capable of recognising well-specified objects or events. Cues and indicators of areas of interest can be generated under less-constrained conditions for interpretation by human analysts. There are still significant limitations in perception for temporal activity, although there is promising research into 'human computation' - human interaction with computer vision processing.
Communications and piloting	Operators commonly control platforms from remote control stations using data links via satellite communications, or using line-of-sight communication links at launch locations. Loss of communications is generally dealt with by pre-placing repeaters (or deploying them when needed), opportunistic use of mobile resources, and/or provision of sufficient on-board autonomy to reduce reliance on central control.
Machine intelligence: planning/ learning/ data analysis	Automated and autonomous systems can achieve common capabilities such as generating optimal plans, monitoring plan execution and problem solving, selecting and allocating resources, analysing data or imagery for particular patterns, implementing or activating the next step in the plan, and reacting to the environment to determine the best action and for learning. For planning, the Planning Domain Definition Language (PDDL) representation was first proposed in 1998 and has since been expanded to incorporate more sophisticated models of time and objectives, events beyond planner's control, preferences and probabilities. PDDL is not yet expressive enough for applications to support quick, contextual decisions about action and those requiring a hierarchical model from strategic to tactical. However, planning systems are now able to solve to (near) optimality problems that require plans with thousands of actions. Two supportive technologies being investigated are mixed initiative systems (which involve the operator in the decision-making) and knowledge engineering tools (for translation and verification of application-specific representational formats). Machine learning is currently effective at identifying specific categories of objects/people/activities for which it has been trained. Some difficulties remain in anomaly detection and identification. Techniques for reducing the amount of required supervision include active learning, transfer learning,

	semi-supervised learning and cross-modal training[1].
Mobile manipulation	The more advanced systems currently have a human operating component such as the manipulator arm while the base platform remains stationary or slowly moves towards the object of interest (such as for bomb-disposal robots). Challenges remain in grasping, multi-arm grasping, and grasping and moving.
Energy storage and management	A lot of smaller systems use batteries or tethers for energy supply. This limits their range compared to the larger systems that can use liquid fuels as a (dense) source of energy. Recently, a solar-powered plane has embarked on a test-flight around the world in a demonstration of applying alternative sources of energy. Hydrogen cell-based systems are now in development that promise significant extension of range [15].
Propulsion and mobility	Unmanned platforms commonly use mobility systems that are similar to those for manned systems, as well as various hybrid approaches such as vertical take-off and landing (VTOL) systems for UAS, and combinations of wheels and treads for UGS. Legged ambulating systems are advancing but are yet to achieve practical efficiency. Bio-mimicry is sometimes used to achieve alternative propulsion methods for underwater systems.
Human-machine teaming and interface	Currently, the human-to-robot ratio is often greater than one, although some programmes have demonstrated a single operator controlling up to four platforms under nominal conditions. This becomes harder with changing conditions and platform failures. Some research focuses specifically on the creation of effective human-robot teams that capitalise on the strengths of both and compensate for the others' weaknesses. This research also relates to improving the human-machine interface to facilitate more natural interaction. For example, some research is being conducted into haptic feedback and direct neural interfaces. Apart from more effective interfaces, the key to reducing the human:robot ratio is believed to be in greater degree of autonomy for the robots.
Multi-agent coordination	In multi-robot research, automated and autonomous systems are often described in terms of their organisation (strongly centralised, weakly centralised, distributed), coordination methods (strongly, weakly, not coordinated), awareness of team members (aware or unaware) and cooperation (explicit, implicit). The system parameters that affect these are communication technology, team composition (human vs. machine, and the types of A3 systems in the team), underlying cognitive systems architecture, and team size. Research is being conducted into development of self-coordinating swarms, although this has not yet been achieved to a practically useful level.

[1] Active learning refers to automatic selection of those examples for labelling that will most improve the overall system performance. Transfer learning means using knowledge acquired from related 'source' problems to deal with a new problem. Semi-supervised learning uses a mix of labelled and unlabelled data to develop accurate knowledge with limited supervision. In cross-modal training, one sensory modality is used to automatically train another.

2.5 Current Challenges for Automated and Autonomous Systems

Despite the remarkable progress of automated and autonomous technologies in the last twenty years, there remain significant challenges. This section offers a more detailed discussion of some of these key areas.

2.5.1 Data Management

There are a number of aspects to managing the data generated by automated and autonomous systems that are not yet adequately addressed and may present specific challenges in the context of Land Logistics operations. They include reliability of data transmission, data security, and data exploitation.

Reliability of data transmission is often dependent on the bandwidth availability and network reliability, with logistic operations commonly getting lower priority in network use.

Data security has gained some prominence in the media lately with demonstrations of hacking of modern cars that allowed hackers to gain control of brakes, engine operation, and door locks [16]. In 2011, an American Lockheed Martin RQ-170 Sentinel UAS was captured by Iranian forces who claim to have jammed the control signals and used GPS spoofing to get the UAS to land in Iran [8]. However, data security in the military context is important across the entire information flow. Various forms of attack can be used to gather information, conduct traffic analysis, force a system into a vulnerable state, take control of the system, modify messages, and conduct denial-of-service attacks. Encryption of the C2 and data links is important for protecting the system operations, Intelligence Surveillance and Reconnaissance (ISR), and other information [8].

Data exploitation has become a significant issue as increasing numbers of sensors are generating increasingly vast amounts of information. This problem exists on both ends of the transmission links:

- Before transmission, large volumes of data may need to be downsized, or the data transmission mechanism must evolve to provide greater bandwidth [8].
- After the data is received, it needs to be used by analysts to draw conclusions for the decision makers. As an illustrative example, the increase in data collected by the Predator UAS for US Department of Defence (DoD) has resulted in 30% increase in the number of analysts required to sort through it [2].

Some suggested solutions entail formatting and prioritisation prior to transmission, use of standard archiving approaches, and making data easily accessible by both anticipated and unanticipated analysts and consumers. Development of autonomous capabilities for common functions such as take-off, landing, navigation to target areas, threat avoidance and health monitoring will help reduce the manning requirements as well as bandwidth requirements for tele-operation [2]. The overall goal is to improve data analysis capability so as to allow human analysts to be employed only in the highest order tasks.

2.5.2 Physical Parameters

Balancing physical parameters such as size, weight, power and cooling (SWaP-C) with payload capacity are a significant challenge for mobile systems such as UAS. Large SWaP-C impedes mobility and manoeuvring, while addition of external payloads can add drag. Some systems are constrained by the power consumption of the payloads, such as cameras and sensors, and survivability systems. The focus is now on modularity of payloads with plug-and-play capabilities. Miniaturisation of on-board systems and platforms addresses some of the issues, as does the use of more reliable and durable components. Use of stronger materials can help reduce the impacts of extreme operational environments with improved abilities to withstand stress, corrosion and other structural effects. The trade-off for lighter yet stronger material is the increased cost of the platform [8].

2.5.3 Power and Energy

Currently, the mobile systems are limited in range with larger internal combustion engine-powered platforms having the longest mission range. Dirigible-type airships can also achieve longer endurance but with lower speeds. Fuel-efficient propulsion and power output are needed to extend endurance and renewable energy sources may help address this issue in the future [8]. Recently, a solar-powered plane has embarked on a test-flight around the world in a demonstration of applying alternative sources of energy. Hydrogen fuel cell-based systems, such as the HYCOPTER developed by Horizon Unmanned Systems in Singapore, show promise in significant extension of range [15].

2.5.4 Navigation

Many mobile systems rely on a combination of GPS and INS. GPS reliance can be a source of vulnerability in network-degraded environments and Inertial Measurement Unit (IMU)-based navigation tends to result in drift over time. Inaccurate or degraded position, navigation and timing (PNT) can, in turn, introduce errors into navigation and sensor cueing.

Probabilistic methods have facilitated recent advances in simultaneous localisation and mapping (SLAM). However, they do not scale well to complex environments with high demands on memory and computation power. They can also be susceptible to sensor noise and unexpected events [2]. GPS-independent methods such as Inertial Measurement Unit (IMU) technology are in development, with focus on reducing drift through regular cross-checks with other methods (such as feature recognition).

2.5.5 Organisational Fit

Expected benefits of automated and autonomous systems can only be realised with effective adoption and integration. There are a number of potential challenges in this space. The complexity of the software means that design space and trade-offs for incorporating this technology into missions are often not fully understood, which can result in unintended consequences. Furthermore, mission objectives often cannot be stated precisely enough to allow planning optimisation and monitoring and adjustments are required along the way. There are also issues around what to monitor within the physical and computational constraints of the systems, when to autonomously replan, and when to refer back to the user or switch to different objectives. Effective operational use may need user training and education, extensive use of autonomy concepts in war-gaming, development of effective feedback mechanisms for lessons learnt, and building trust in automated and autonomous systems [2].

Integration within the existing processes also means that automated and autonomous systems will need to work with other technologies. For example, air-space de-confliction will be required for dense manned-unmanned system operations [2].

In terms of logistic support, the example of US Department of Defence (DoD) shows the consequences of rapid deployment of a new technology. The first robotic systems deployed in Middle East were fast-tracked through the capability acquisition process. This meant that manning concepts (including concepts of operation and associated training) were immature or had not been developed, spare parts were often unavailable, and sparing/logistic/maintenance requirements were not well defined [2].

2.5.6 Test and Evaluation

The fact that the software for automated and autonomous systems may interact with the environment and operate in a non-deterministic manner presents a challenge for the testing and evaluation (T&E) agencies that are used to full patch regression testing with validation of every individual requirement. New processes need to be developed for T&E and to capture the nature and scale of interactions between the subsystems and between the system and the operator. In particular, T&E challenges require [2]:

- Methods for defining test cases and expected results that deal with the challenge of listing all the conditions and non-deterministic responses that the systems may generate in complex environments
- Techniques and metrics for confirming that the system performs as intended
- Interfaces that allow the users to see the basis of the system decisions
- Relevant test environments with direct and indirect users (possibly with use of simulation).

The T&E challenge affects a number of regulatory frameworks. An example of this is the airworthiness code for UAS that would have to take account not only the standard set of airworthiness factors but also C2 data links, detect-and-avoid technologies, automation and level of autonomy [14].

2.5.7 Human-Machine Interface

In terms of human-machine interface (HMI), a significant challenge is in achieving mutual predictability (who is doing what and when), directability for specifying objects and adapting to the unexpected events, and common ground (language and protocols to ensure sharing of same goals and information). Other HMI gaps are: interfaces that support rapid training and are designed around human cognitive attributes; visibility of what the system is doing and why; and effective human-system interaction mechanisms using natural language and gestures.

Research is currently being conducted into the development of more natural user interfaces with haptic feedback and direct neural links [2]. An example of a more advanced haptic project is the 'symbiotic system' concept, such as a suit that a pilot can wear that allows him or her to 'feel' parts of the plane through vibration, heat or other signals. In turn, the plane can monitor the pilot, including sleep cycles and fatigue [17]. BrainGate technology uses brain signals to control equipment such as a computer mouse, a remote control, robotic arms, etc. The Defence Advanced Research Projects Agency (DARPA)'s Brain-Interface Project is now funding further research into this area. Users report that the linked machines become almost an unconscious extension of the body [17].

A direct consequence of the amount of data generated by automated and autonomous systems is the increase in manning requirements. In fact, the US Air Force has recently declared that its most significant staffing issue is manning its unmanned platforms [2]. This means that higher levels of autonomy are required with better sensors, faster processing and better positioning to reduce this level of human supervision [17].

2.6 Technology Scan for Different Types of A3 Systems

2.6.1 Logistic Information Systems

2.6.1.1 *Business Intelligence Solutions and Inventory Management*

The nature of LIS is evolving from inventory management to more sophisticated decision support and predictive analytics. The overarching concept of a 'logistic supergrid' for coordination of multiple partners is currently limited to specific shipping modes, geographic locations and trading partners [18]. Various companies such as METASONIC and Shipwire Enterprises now also offer web-based, configurable logistics-on-demand services as a type of service outsourcing. This helps reduce the cost of installations, upgrades and maintenance fees for commercial organisations [18].

Inventory management is commonly facilitated by warehouse control systems (SAP[2], Forte, Redwerks, etc.), inventory management software (MILIS[3], CPM[4]), voice-directed picking technology (topVOX, Zetes, VoxWare) and slotting optimisation tools for larger warehouses (SAP, Optricity and others) [5]. In the ADF, MILIS is used to manage inventories within difference warehouses and districts, while the US Army has invested in GCSS[5]-Army and in the Logistics Modernisation Programme (LMP) Enterprise Resource Planning (ERP) systems developed by SAP [19]. The systems are designed to facilitate

[2] Systems, Applications and Processing
[3] Military Integrated Logistic Information System
[4] Commercial Project Management
[5] Global Combat Support System

more efficient materiel flow and stock picking, although integration of stand-alone applications often presents a challenge for larger organisations.

2.6.1.2 *Supply Chain Execution Systems*

Supply Chain Execution (SCE) software is used to coordinate warehouse operations as well as the supporting processes. The more sophisticated systems such as 4flow, Oracle and Logivations software have predictive analytics capability and can be used for modelling and simulation of logistic conditions to test possible future scenarios. Companies such as DHL and Amazon use anticipatory logistics and anticipatory shipping based on both internal and external information sources [20].

2.6.1.3 *Asset Tracking Technology*

Management of supply chain operations is assisted by various asset tracking methods such as different forms of Radio-Frequency Identification (RFID) and indoor localisation. Real-time tracking of assets and their condition can also be integrated within larger supply chain management systems as is done by the systems such as Fraunhofer smaRTI and TiLO. These types of technologies underpin the emerging concept of the 'Internet of Things' (IoT) with sharing of information between 'smart' objects, equipment and infrastructure [5]. Real-time tracking involves continuous data transfer of information such as shipment position, condition and integrity and can be fully integrated with professional smart mobile devices and apps. Examples include Agheera real-time services and Bag2Go. In addition, new generation mobile order management apps allow users to enter and manage shipment orders in real time when on the move (e.g. DHL Activebooking) [18]. However, big data volume, velocity and diversity present challenges for existing analytical systems. The available solutions often don't work across organisational boundaries and a lot of financial investment is required to enable end-to-end application in supply chains.

2.6.1.4 *Condition-Based Maintenance*

Sensors in objects also enable Condition Based Maintenance (CBM) for achieving maintenance efficiencies and better operational availability of platforms. An example of this is the General Electric's SmartSignal tool that generates individualised models for assets with histories and deployment schedules [21, 22]. In the longer term, this type of information enables more efficient and effective fleet management. CBM and Health and Usage Monitoring Systems (HUMS) are extensively used in aircraft and in some commercial land vehicles, although less so in military Land vehicles. HUMS/CBM for structural health monitoring continues to develop and mature. The key challenges for this technology remain in the areas of data transmission, exploitation and dissemination as well as the cost of technology integration. Research also continues into development of accurate prognostic algorithms for prediction of failure before it occurs.

2.6.1.5 *Decision Support Tools for Distribution Tasks*

Support tools for logistics distribution are available for 3D design of loads (e.g. Tops Software, MagicLogic) and real-time route optimisation (e.g. Quintiq, Roadnet Technologies, Telogis). The systems are reasonably mature and are evolving from stand-alone applications to integrated modules of larger SCE systems [5, 23].

2.6.2 Unmanned Aerial Systems

UAS come in a wide range of shapes and sizes from mini-UAS to large airframes. Their capabilities and applications vary accordingly with differences in range, endurance and payload capacity.

2.6.2.1 *Mini-UAS*

Mini-UAS are commonly used for tactical ISR tasks. They can be hand-launched by soldiers and are usually electrically-powered for relatively quiet operation. However, their size and battery requirement restricts their payload capacity and range. Examples of currently used military mini-UAS are Lockheed Martin's Desert Hawk; the Aero Vironment's Dragon Eye and Raven; and Elbit Systems' Skylarks [13]. Some systems combine different mobility mechanisms. For example, the University of Maryland's Robo Raven V is a hybrid that uses both propellers and flapping wings [24-26]. DARPA is funding research into advanced perception and autonomy for urban patrols and for searching buildings [27]. In Land Logistics operations mini-UAS are more likely to be used for supporting security and ISR tasks, although they have also been used for inventory management tasks in warehouses in Germany.

2.6.2.2 *UAS for Last-Mile Logistics*

A different form of small UAS is the 'drone' designed for last-mile logistics. Today most big players in the courier express parcel sector have UAS studies and research projects. Examples are DHL Parcelcopter, Google[x] Project Wing and the Belgian VTOL version, VertiKUL [18, 28, 29]. These systems are unlikely to replace standard delivery methods in military logistics. However, they may be appropriate for urgent deliveries into denied, contested and isolated environments and for last-mile distribution to dispersed forces. The limitations of these UAS are their small payload capacity (around 1-5 kg) and limited range; for example, VertiKUL has a range of up to 30km. They also have a noise signature and are fairly sensitive to environmental perturbations. As is the case for other A3 systems, they have a limited ability to navigate autonomously through cluttered complex environments. An interesting development for smaller UAS has been in construction of hydrogen fuel cell powered models, such as HYCOPTER from Horizon Unmanned Systems. HYCOPTER makes use of its frame to store energy in the form of hydrogen and its endurance is approximately 8-10 times longer than equivalent battery-powered systems [15].

2.6.2.3 *Small, Long-Endurance UAS*

Slightly larger, long-endurance UAS are commonly rail-launched and have a range of up to 100km or several hours of operation. Examples include Boeing's Scan Eagle, Advanced Ceramics' Silver Fox, and MMIST[6] Snowgoose (a self-guided parafoil UAS). The Australian Army now uses Shadow UAS developed by AAI Corporation[7], whereas Scan Eagles have been used by the ADF in Afghanistan since 2007. These types of UAS are most commonly used for ISR tasks. Systems such as Snowgoose are ideally sized for discrete delivery of small quantities of logistic supplies and are less expensive when compared with most other unmanned cargo systems under development. The US Quick-Meds programme has also conducted demonstrations, with Shadow UAS dropping 9kg of medical supplies to forward areas [13]. However, it should be kept in mind that the launch-and-land style of UAS can be difficult to return to their point of origin once they've landed at the destination and delivered their payload.

2.6.2.4 *Large, Long-Endurance UAS*

Larger long-endurance UAS have a substantial payload capacity and long endurance, often with the use of internal combustion engines. Examples include Israel Aerospace Industries' Heron aircraft, and Northrup-Grumman's Hummingbird and Fire Scout (with VTOL capabilities) [13]. An unmanned variant of Lockheed Martin's K-MAX helicopter was used in Afghanistan since 2011 [19, 30]. More advanced designs include the Aerial Reconfigurable Embedded System (ARES) developed by Lockheed Martin's Skunk Works together with Piasecki Aircraft. ARES was expected to begin its flight test period in 2015. The ADF is expecting to field seven MQ-4C Triton UAS by 2020 for use in maritime patrol and surveillance [31]. Fixed wing (FW) UAS of this size are used predominantly for persistent ISR [19, 32]. However, the rotary wing (RW) and VTOL versions are well suited to cargo distribution tasks. Their limitations are characteristic of A3 systems in general and include costs, data analysis support requirements, electronic countermeasures and jamming. A less expensive option is fitting the existing aircraft with autonomy kits such as the Autonomous Aerial Cargo/Utility System (AACUS) developed for the US DoD. These kits are designed to be platform agnostic and may help avoid the costs of fleet replacement [33].

2.6.2.5 *Precision Air-Drop*

An alternative approach to autonomous distribution is precision air-drop, such as that demonstrated by the US Joint Precision Airdrop Systems (JPADS). JPADS use airborne guidance units, electromechanical steering actuators and a steerable canopy to guide payloads to within approximately 80-100 metres of their landing points (from 25,000 feet). The family of JPADS range from microlight (10-150lb) to medium sized (15,000-42,000lb). The technology has been trialled successfully in Afghanistan, although further development is required to increase precision of delivery so as to be able to place the

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[6] Mist Mobility Integrated Technology
[7] Originally Aircraft Armaments, Inc.

payload within a forward base's perimeter [19]. Current research effort in collaboration with Draper technology focuses on improving precision and use of imagery rather than GPS for navigation [34].

2.6.2.6 *Hybrid UAS*

Some hybrid systems are being developed to operate in more than one domain. The Black Knight Transformer developed by Advanced Tactics is a VTOL aircraft with modular design for a variety of payloads. One of these is a drive train unit for driving on the ground [35]. Smaller systems include Berkeley's robotic bird (H^2Bird) that launches off the back of a robotic cockroach (VelociROACH) [36]. In theory, these types of hybrids can extend reach into areas that are difficult for domain-specific systems to reach on their own. However, further development is required to mature this technology to a practically useful level.

2.6.2.7 *UAS Countermeasures*

UAS of various types are gaining prominence on the battlefield. The US Army began UAS operations with 54 units in 2001 and as of 2014 had over 4,000 units of various sizes and capabilities [14]. As a result, UAS countermeasures are also being developed in a number of countries. Currently fielded systems are based on destruction (with bullets or missiles), catching UAS with nets (fired from the ground or carried by other drones), jamming, spoofing, and other directed energy technologies such as lasers. One example of a sophisticated net-based system for safe capture of UAS is SkyWall 100 device developed by UK OpenWorks Engineering. The bazooka-style devices uses compressed air launcher to fire smart projectiles that open and release a net when they reach the drone. A high-tech scope is used to lock onto and track the UAS [37]. Although not very many countermeasure systems are deployed at the moment, they are expected to become a standard feature of military operations in the future [38].

2.6.3 Unmanned Ground Systems

The variety presented by UGS is even greater than that of UAS due to greater number of options for propulsion and mobility designs, and a large number of applications.

2.6.3.1 *Soldier UGS*

Smaller UGS on wheels or treads used for military purposes have been termed 'soldier UGS' due to their use for tactical tasks. They include systems such as Packbot by iRobot, Dragon Runner, Bombot and others [13]. Talon, a robotic platform from Foster-Miller was used at Ground Zero and was one of the earliest soldier UGS deployed to Middle East. It is a very robust, remotely piloted system and its armed version, SWORDS[8], can drive through snow, sand and go up to 100 feet underwater [17]. On the smaller scale, MARCBOT looks similar to a toy truck and has been used for scouting missions and to

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[8] Special Weapons Observation Reconnaissance Detection System

check under vehicles for explosives [17]. In terms of logistic operations, soldier UGS are mainly useful for security and environmental monitoring tasks, including chemical, biological, radiological and nuclear (CBRN) event detection. The systems are limited in range due to battery power restrictions and often limited reliability of radio-communication; they also have relatively small payload capacity. The cost of some systems is quite high with Talons costing over US $200,000 each, and MARCBOTS presenting a cheaper option at around US $5,000 each [17].

2.6.3.2 *Squad Support Systems*

The mobile UGS that can keep up and interact with soldiers are being developed as 'squad support systems'. They include both driverless vehicles of various sizes, and legged ambulating systems. One of the more publicised legged robots has been the Boston Dynamics' Legged Squad Support System (LS3), a rough terrain robot designed to travel with unmounted troops, carry 180kg of gear over 30km mission and last 24 hours[9] [39-42]. Similar systems under development include MIT's Cheetah robot [43], Israeli Aerospace Industries' REX 4x4 robotic logistic carrier [44, 45] and Lockheed Martin's Squad Mission Support System (SMSS) [45]. These robots are designed to assist soldiers with load carrying and evacuation and act as a mobile source of electrical power. The key limitations are in traversing uneven terrain and dealing with obstacles, which the different designs overcome to varying degrees. Further advances are also required in control, artificial intelligence, user interface, computer vision and system robustness to make the systems practical. Their cost may also slow down their adoption on a larger scale.

In the civilian market, security robots such as the K5 robots (by Knightscope) [46] and Guardium Mk1 (IAI[10] and Elbit Systems) have been used for security patrols. Guardium Mk1 robots are currently patrolling the perimeter of the Tel Aviv International Airport [47]. In this scenario, robots replace humans in monotonous and sometimes dangerous security work and leave strategic decision-making to humans.

2.6.3.3 *Driverless Vehicles*

Driverless vehicles have become an area of great interest with most major automotive manufacturers now developing their own versions. Autonomous haul trucks (AHTs) are gaining popularity for mining applications [48]. In military environments, driverless vehicles such as the US Army Tank Automotive Research, Development and Engineering Center (TARDEC)'s Stryker have been tested for robotic convoy leader tasks [13]. The DARPA-sponsored Crusher vehicle is a larger example at over five meters long and with payload capacity of 3600kg [13]. The US Naval Surface Warfare Centre (NSWC) and TORC Robotics have been testing vehicles such as the Ground Unmanned Support Surrogate Autonomous Internally Transportable Vehicle (GUSS AITV) that is air-transportable and can switch between manual driving, tele-operation and autonomous modes [49].

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[9] Following Google's acquisition and subsequent divestment of Boston Dynamics, further development of military applications of LS3 is now in doubt.
[10] Israel Aerospace Industries

Driverless vehicles can be used for cargo delivery and logistic distribution in reasonably structured, controlled environments. In the military context, however, there is also considerable interest in developing systems that can deliver cargo to contested, isolated areas and to dispersed troops. They can also be used to lead convoys to ensure route safety, or combined into autonomous and semi-autonomous convoys for cargo distribution tasks in controlled areas. Challenges include the ability to operate in environments with degraded GPS and computer networks, the overall cost of the hardware, and the distinct electronic signatures of the active sensors that these vehicles use.

Driver-assist technologies can be viewed as an intermediate step to full vehicle autonomy and are now incorporated into the latest models of commercial vehicles. They include Lane Departure Warning, Lane Keep Assist, Autonomous Emergency Braking, Adaptive Cruise Control, Automatic Parking and Driver Fatigue Monitoring. They are predominantly designed for civilian traffic environments [50]. Another intermediate step is the autonomy applique systems for existing vehicles, such as Lockheed Martin's Autonomous Mobility Applique System (AMAS) [19, 51, 52]. Although the more sophisticated kits can cost upwards of $100,000 per vehicle, they present a less expensive option than vehicle replacement.

2.6.3.4 *Engineering, Construction and Material Handling UGS*

Automation has also been used in engineering, maintenance and warehousing tasks. Various construction systems such as excavators have been equipped with autonomy kits or designed for semi-autonomous operation [45]. A bricklaying robot called SAM (Semi-Automated Mason) has been fielded by Construction Robotics [53-55]. For warehouses, Vecna is developing the Rapid Palletising Robot (RPR) [56, 57]; Leibniz University have partnered with STILL International to build an autonomous forklift capable of self-localisation based on laser mapping of roof structures [45]. Clearpath Robotics have demonstrated OTTO, a heavy load material transporter for warehouses with five pilot programmes underway [58]. In the military context, these types of systems can help automate construction, demolition and materiel handling tasks, thus removing personnel from potentially dangerous environments. Some of these tasks can be performed via tele-links, allowing use of skilled operators located at the National Support Base (NSB). However, the cost of these systems needs to be balanced against the probability that such tasks would need to be conducted in contested environments.

2.6.3.5 *Biomechanoids*

A technology that is conceptually interesting but is still in the very early stages of development is incorporation of robotic systems into live biological organisms, producing 'biomechanoids'. North Carolina State University researchers have demonstrated 'cyborg' cockroaches equipped with microphones and some directional systems. Projected applications include assisting with locating survivors in humanitarian assistance/disaster relief (HADR) scenarios, although a lot of practical and technological barriers are yet to be overcome [59].

2.6.4 Unmanned Maritime Systems

Although UMS are a large emerging market, their applications for Land Logistics are likely to be restricted to supporting ISR tasks, water quality monitoring and collection of other data. Research programmes are ongoing to develop both surface and underwater systems that can exist at sea for months or years at a time. Some, like the National University of Singapore (NUS) turtle robot, mimic biological systems for mobility [60]. With improved manoeuvrability, the turtles can be used to survey small and narrow places like underwater crevices. At this stage, there is limited use for UMS in Land Logistics domain, although some functions would be relevant for amphibious operations.

2.6.5 Swarms

Swarming refers to cooperative behaviour among networked autonomous systems that gives rise to a coherent, intelligent whole [61]. The key concept of swarms is high-level control of multiple systems by a single operator facilitated by a significant level of self-organisation within the swarm itself. The systems can comprise UMS/UGS/UAS of various sizes and functions. Swarming has become an area of great interest in ISR and combat domains due to the tactical advantage that swarms present by their sheer numbers. The US Navy has recently demonstrated the ability of a swarm of autonomous surface vessels to intercept and surround a potential hostile vessel [61]. The US Low-Cost UAV Swarming Technology (LOCUST) programme has conducted demonstrations of swarming UAS that are launched into the air and perform defensive and offensive missions with autonomous collaborative behaviour; they can be launched via a tube using compressed air [62-64]. DARPA's 'Gremlins' programme looks at developing technology to launch swarms of low-cost reusable UAS over great distances and then retrieve them in mid-air [65, 66]. Although there is occasional consideration of the potential logistic applications of swarms (such as in-situ resource scavenging), their most significant impact is likely to be as part of combat operations. From a logistician's point of view, they need to be considered primarily as a source of threat to convoys, bases and specific assets.

2.6.6 Human Augmentation Systems

For the purposes of this report, 'human augmentation system' is an umbrella term used to describe all manner of automated and autonomous systems that enhance human functions.

2.6.6.1 *Exoskeletons*

Exoskeletons for human operators are an example of such augmentation technology that has been developed for medical, industrial and military purposes. Unpowered exoskeletons such as Lockheed Martin's FORTIS exoskeleton [67], transfer loads through the device to the ground and allow the operator to handle heavy tools or materiel. The US Navy is currently testing two FORTIS exoskeletons [68]. Powered exoskeletons tend to allow for greater load carrying capacity. For example, Lockheed Martin is currently developing the Human Universal Load Carrier (HULC) exoskeleton [69] that will allow troops to carry up to 200lb (approximately 90kg). The Tactical Assault Light Operator Suit

(TALOS) powered armoured suit is being tested by the US DoD and incorporates protective features and some wound treatment capabilities [70]. For logistic operations, exoskeletons can reduce the requirement for other forms of Material Handling Equipment (MHE). The drawbacks of powered exoskeletons are mainly in their cost and high power requirements that limit operating time.

A more compact version of this technology is the undersuit that assists with load carrying and reduces strains on particular joints. Examples include the smart suit developed by the Wyss Institute [71] and the Flexoskeleton developed by DST Group [72]. The Flexoskeleton weighs only 3kg and transfers over 60% of weight from soldier's load to the ground. These systems can help troops walk further, tire less easily and carry heavy loads more safely. For logistic operators, there is a benefit in reducing injuries associated with materiel handling tasks.

2.6.6.2 *Cognitive Augmentation*

In terms of cognitive augmentation, some research programmes look at automated and autonomous systems for adapting the volume and method of information presentation to a soldier based on their cognitive load. User stress is determined through EEG/ERP[11], eye tracking, pupil dilation, body posture, heart rate and galvanic skin response. The demonstrated improvement in mission performance from DARPA-sponsored research has been from 68% to 96% [73, 74]. However, currently, the US Army is focussing on the use of this technology for training rather than for operations. Barriers to transition from the laboratory environment to an operational environment includes finding suitable EEG/ERP sensors that don't need conducting gel, the ability to process signals in real-time, and having systems working while users are in motion and under difficult environmental conditions.

2.6.6.3 *Augmented Reality*

A different approach to augmenting human processing capacity is the use of Augmented Reality (AR). AR was first introduced in the maintenance and repair sector in 1990, but is now increasingly used for logistic operations. For example, SAP & Vuzix AR for warehouses provides real-time data streaming from SAP systems to AR glasses, enabling hands-free information access [18]. Applications lie in the execution of warehouse operations such as picking, assembly, maintenance, staff training and risk management. Remote assistance through AR has applications in tele-maintenance and tele-medicine among other logistic functions. Barriers are mainly in system integration with existing software and data transmission for tele-links.

[11] Electroencephalogram/Effective Refractory Period (in a cardiac cycle)

2.6.7 Power and Energy Management

2.6.7.1 *Soldier Power Integration and Management*

New developments in energy sources or battery designs fall outside the scope of this report. However, automation concepts are also being employed in smarter integration and management of all of the various devices that are carried by soldiers today. The US Army has been using the Integrated Soldier Power and Data System (ISPDS) with up to four devices powered by a central conformal battery [19]. Apart from reducing the number and type of batteries required by soldiers, ISPDS also allows sharing of data across devices and provides visibility of power usage. More advanced designs currently in development look at integration of devices on rifles and helmets as well. In Australia, a system developed by Tectonica called SIPS (Soldier Integrated Power System) has been tested for the ADF [75].

2.6.8 Health Systems

Automated and autonomous systems have found applications across a wide range of health functions, some of which are discussed here.

2.6.8.1 *Autonomous Patient Stabilisation*

Autonomous patient stabilisation is of great interest to military organisations in terms of extending the time that battle casualties can survive prior to getting to a point of definitive care. The US Office of Naval Research (ONR) has funded the development of the Autonomous Critical Care System (ACCS) as an integrated hardware 'system of systems' that provides automated medical care including vital signs monitoring and appropriate intervention. This technology is in very early stages of development; research challenges yet to be overcome include control of internal bleeding without surgical access, and automated resuscitation measures that increase blood volume, deliver oxygen to ischemic tissues, replenish coagulation factors and modulate immune response [76].

2.6.8.2 *Casualty Evacuation Systems*

The concept of casualty evacuation (CASEVAC) via UAS has raised some concerns in terms of its operational, clinical, ethical and legal aspects. However, NATO now considers that UAS may be used for this role under certain circumstances and has published Safe Ride Standards for CASEVAC using UAS [77]. The UGS CASEVAC systems that have been developed to prototype stages include BEAR (the Battlefield Extraction-Assist Robot) from Vecna Technologies [78]. BEAR is a self-balancing tracked platform that can carry a single soldier. In a different approach, the Robot Combat Casualty Extraction and Evacuation Programme at Applied Perception [79] looks at using two UGS – a smaller UGS for retrieving soldiers from dangerous areas and a larger one for transportation to medical care [13].

2.6.8.3 *Advanced Prosthetics*

The most advanced prosthetics today are sophisticated electronic systems that can be controlled directly by the brain via neural interfaces implanted in the brain's motor cortex. The interfaces allow amputees and other operators to control auxiliary or supernumerary limbs in a more natural, fluid manner. An example of an advanced prosthetic device without a neural interface is the Deka Arm System developed by DARPA that uses inputs such as electrical signals from muscle contraction, wireless signals from sensors on the feet and force sensors in the prosthetic hand [80]. These types of systems are more likely to be of interest in treatment and rehabilitation of injured soldiers back at the National Support Base (NSB), rather than for casualty treatment during operations.

2.6.8.4 *Robotic Surgery*

Robots for surgical procedures such as the Da Vinci robot [81] are now becoming mainstream tools for certain types of operations in civilian hospitals [82]. A slightly different approach is the miniaturised surgical robot that can be placed entirely within the abdomen for surgical procedures relating to the bowel and colon. It has the advantages of not requiring a dedicated operating room or specialised infrastructure and reduces the need for open surgery for some abdominal procedures [83-85]. Some assistive automated devices have been developed for specific procedures such as venepuncture [63, 86, 87]. The venepuncture procedure can be controlled via a tablet, which also allows tele-control. There are some cultural issues around acceptance and trust in robotic systems for these tasks, but they are gradually gaining wider acceptance.

2.6.8.5 *Networked Portable Diagnostics*

Miniaturisation and networking of diagnostic devices is now enabling rapid diagnosis in isolated areas. Daktari Diagnostics has produced a portable CD4[12] device for diagnosing human immunodeficiency virus (HIV) in third-world countries [88]. Columbia University researchers have developed a portable Enzyme Linked Immunosorbent Assay (ELISA) - based device that plugs into a smartphone's headphone jack for power [89, 90]. Digital stethoscopes from several manufacturers can digitise and visualise the sound of a heartbeat [91, 92]. Significantly, a lot of these diagnostic devices also connect to databases for decision support. Decision support to diagnosis is also automated in systems such as IBM's Watson, which has been tested in matching clinical trials to patients and developing personalised treatment plans [93].

The devices are portable and are faster and cheaper than conventional tests, although some microfluidic-based systems are still limited in the range of pathogens for which they can test. For health support operations, they reduce the need for deployment of large, expensive pathology laboratories and specialists. Faster diagnosis means a better informed

[12] CD4 cells are a type of white blood cell also known as T-helper cells. CD4 cell count is an indicator of immune system strength and is an indicator of the stage of HIV disease.

health planning process. For military environments, software integration and connectivity to cloud-based databases may present some challenges.

2.6.8.6 *Health-State Monitoring*

Health-state monitoring devices have become widespread for consumer fitness coaching. These include FitBit, Apple Watch and others [94]. There are also more sophisticated devices for patient health-state monitoring. For example, Rijuven markets a wireless electrocardiogram (ECG)-based tele-medicine and biofeedback patch that measures the ECG, heart rate, heart rate variability, respiratory rate, sleep position, restfulness, breathing index and energy levels [95]. The US Army Medical Research and Materiel Command are currently developing physiological sensors that soldiers can wear for remote monitoring [96]. In the military context, these types of systems can be used to monitor and adjust water or calorie consumption, track fatigue levels and sleeping patterns, detect injuries, and triage casualties. With location information, they can be used to guide manned or unmanned evacuation assets to the casualties. However, most commercial systems are not suitable for direct integration with military equipment and adjustments would need to be made to both technology and processes in order to incorporate persistent health-state monitoring into military operations. The issues of data management are also substantial for this technology in terms of transmission of large amounts of data, security of access, ability to exploit the information, and in terms of software system integration for e-health and C2 applications.

2.6.8.7 *Synthetic Environments*

Synthetic environments have gained popularity for soldier training across a range of military functions due to lower costs and greater flexibility in scenario adjustments compared to the use of actual physical systems. This is also true for training of medics and other medical professionals. An example is the Wide Area Virtual Environment (WAVE) used by the US DoD where sights, sounds, smells and stressors of the battlefield are simulated to help immerse medical personnel in the 'fog of war'. The synthetic environments are commonly combined with sophisticated medical mannequins or part-task trainers to assist in particular injury scenarios [80].

2.7 Applications of Automated and Autonomous Systems for Land Logistics

Unlike combat support applications such as ISR, combat tasks, and mine clearance, the role of automated and autonomous systems in logistic operations has not been well defined. This is likely to change as insurgency-style conflicts in the Middle East place more support personnel in danger, and operational planners start looking to robotics for dull, dirty and dangerous tasks. This technology offers the potential benefits of preventing casualties and having more efficient and continuous logistic operations with reduced logistic footprint.

The diagrams in each of the four sections below summarise the potential logistic applications based on the technology scan results. The Technology Readiness Levels

(TRLs) (see Appendix B) are shown in orange for lower maturity technology, yellow for medium maturity and green for technology that has already been used on operations.

A review of technology reports specifically on military technology [2-4, 8, 9, 13, 17, 97]) suggested a number of logistic applications; these are indicated by red dots in the diagrams. Further discussions were held with ADF Logistics Officers at the Logistic Officer Advanced Course (LOAC) at the Army School of Logistic Operations (ASLO) in October 2015 regarding the use of emerging technologies in Land Logistics. The more promising applications for automated and autonomous systems identified during these discussions are indicated by blue dots.

2.7.1 Applications for Supply and Transport

Examination of applications for supply and transport has generated the largest list out of all the functional groups. Figure 3 summarises the potential applications across different types of automated and autonomous systems, the Technology Readiness Level (TRL)[13] of the technology, and the areas of interest based on literature review (red dots) and ADF Logistics SME discussions (blue dots).

Review of military technical reports indicates a great focus on exploitation of business intelligence and supply chain execution software for design, evolution and optimisation of distribution networks. This applies to NSB processes as well as deployed forces. Asset tracking systems and sensors for improved asset visibility are considered valuable in providing a clearer logistic Common Operating Picture (COP) and as an aid for logistic planning decision support.

In terms of physical A3 systems, there is a focus on UAS and UGS for distribution of materiel to isolated and contested areas and to dispersed forces, as a way of extending the capabilities of logistic support. UAS are perceived to be useful in discrete delivery of small quantities of supplies, or for resupply from sea-based assets.

There is also interest in driverless vehicles for cargo distribution in both structured and unstructured environments. It is recognised that current systems deal better with structured environments with known routes in uncontested spaces. However, the potential for removing human drivers from harm has resulted in the development of driverless vehicles for deliveries to isolated/contested areas, and for use as convoy leader vehicles to help ensure route safety. Current convoys are often preceded by a security escort for ISR. An unmanned vehicle could perform this role with payloads such as video, infrared imagery, electronic countermeasures packages, and improvised explosive device (IED)/land-mine detection packages. A single mention was found in literature of the possibility of pre-deployment of UGS to strategic positions for faster resupply once operations commence.

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[13] A description of the Technology Readiness Levels is provided in Appendix B.

Some value is also seen in the use of squad support UGS for carrying loads including weapons, ammunition, water and fuel. The advantage is in reducing the burden on the soldier, giving better agility, endurance and manoeuvrability over long distances. However, it is generally recognised that these systems are not yet developed to a practically useful level.
For material handling tasks in distribution, exoskeletons and automated MHE can have uses in assisting with loading and unloading.

Some mention can be found of using swarms for in-situ resource scavenging, however swarms are more likely to be developed for combat and ISR applications.

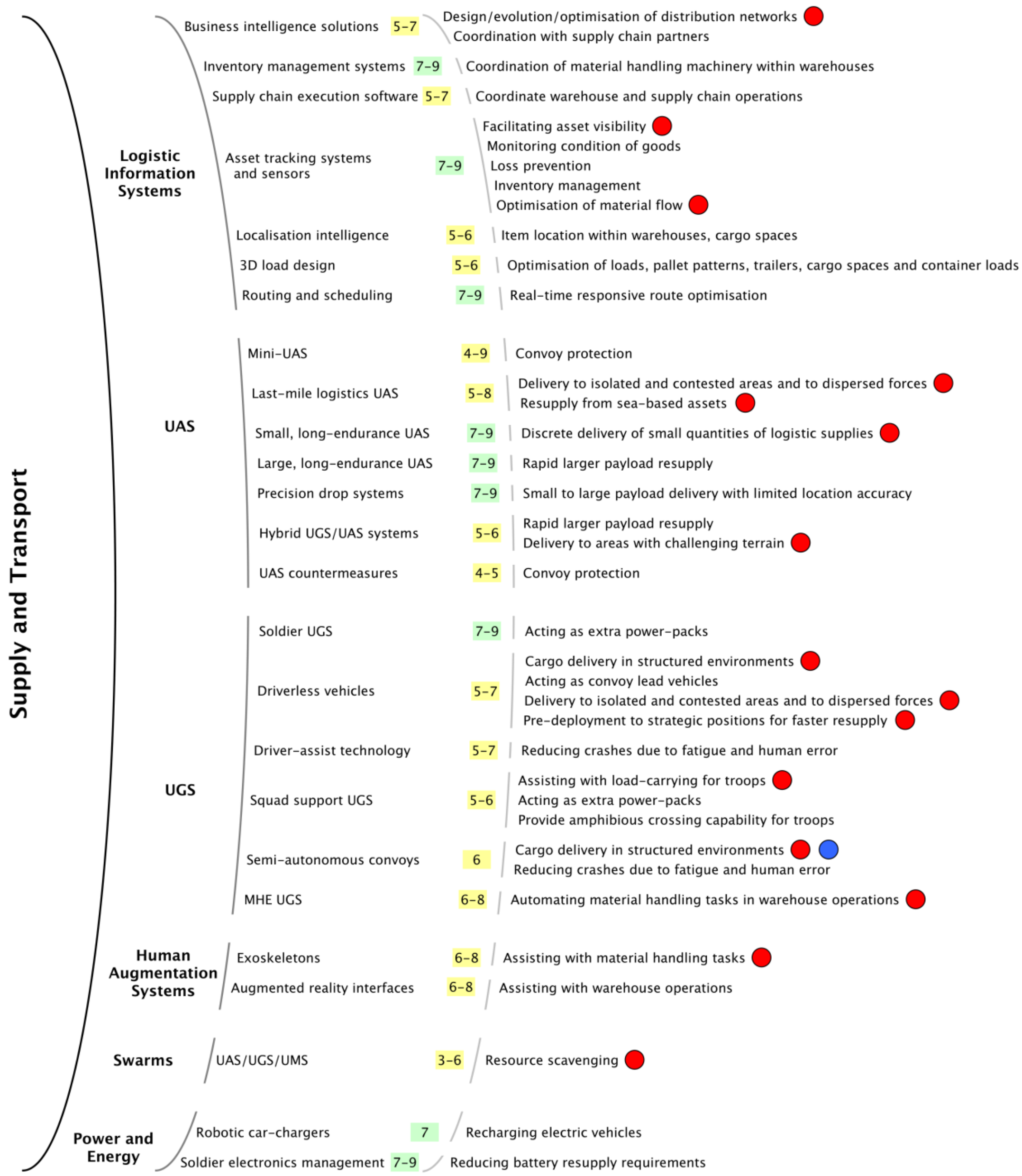

Figure 3: Applications of automated and autonomous systems for distribution

By contrast, discussion with ADF logistic officers has focused predominantly on the use of semi-autonomous convoys for cargo delivery in structured environments (rather than for last-mile logistics). Convoys can operate in autonomous or semi-autonomous manner with robotic follower elements to reduce the number of soldiers required to move supplies. This is the only overlapping application in this area.

2.7.2 Applications for Engineering, Maintenance and Field Services

A summary of potential applications in engineering, maintenance and field services is given in Figure 4. It can be seen that there are generally fewer applications highlighted, with focus primarily on the use of networked sensors for CBM and, in the longer term, for better fleet management and soldier UGS for routine maintenance tasks. CBM is the only area of convergence between military technology reports and discussions with ADF Logistics Officers. Additional applications highlighted in the reports include the use of engineering and construction UGS to assist with construction and demolition tasks in dangerous environments. Automated MHE UGS are also seen as useful for engineering and construction tasks where these occur in contested environments.

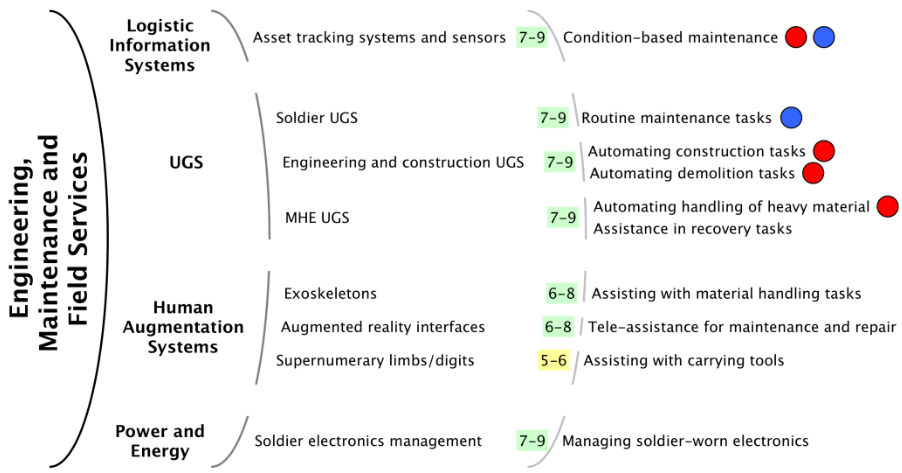

Figure 4: Applications of automated and autonomous systems for engineering, maintenance and field services

2.7.3 Applications for Health Services

Applications in health are diverse and have generated substantial interest in military organisations. They are summarised in Figure 5.

In this instance, the applications proposed by ADF Logistics SMEs are more extensive than those found in the reviewed military technology reports. The latter tend to look at the use of UAS and squad support UGS to assist with casualty evacuations, biomechanoids to assist in searching for survivors, automated portable devices for rapid screening, diagnosis and decision support, and persistent telemetry. All of these applications (bar the use of biomechanoids) were also discussed by the ADF Logistics SMEs, but also suggested the use of UAS for delivery of critical medical supplies to casualties, large UAS to bring surgical capability forward, AR interfaces for tele-assistance and tele-medicine, automated patient stabilisation systems, advanced prosthetics, and telemetry for triaging casualties, guiding evacuation platforms and real-time soldier health-state monitoring.

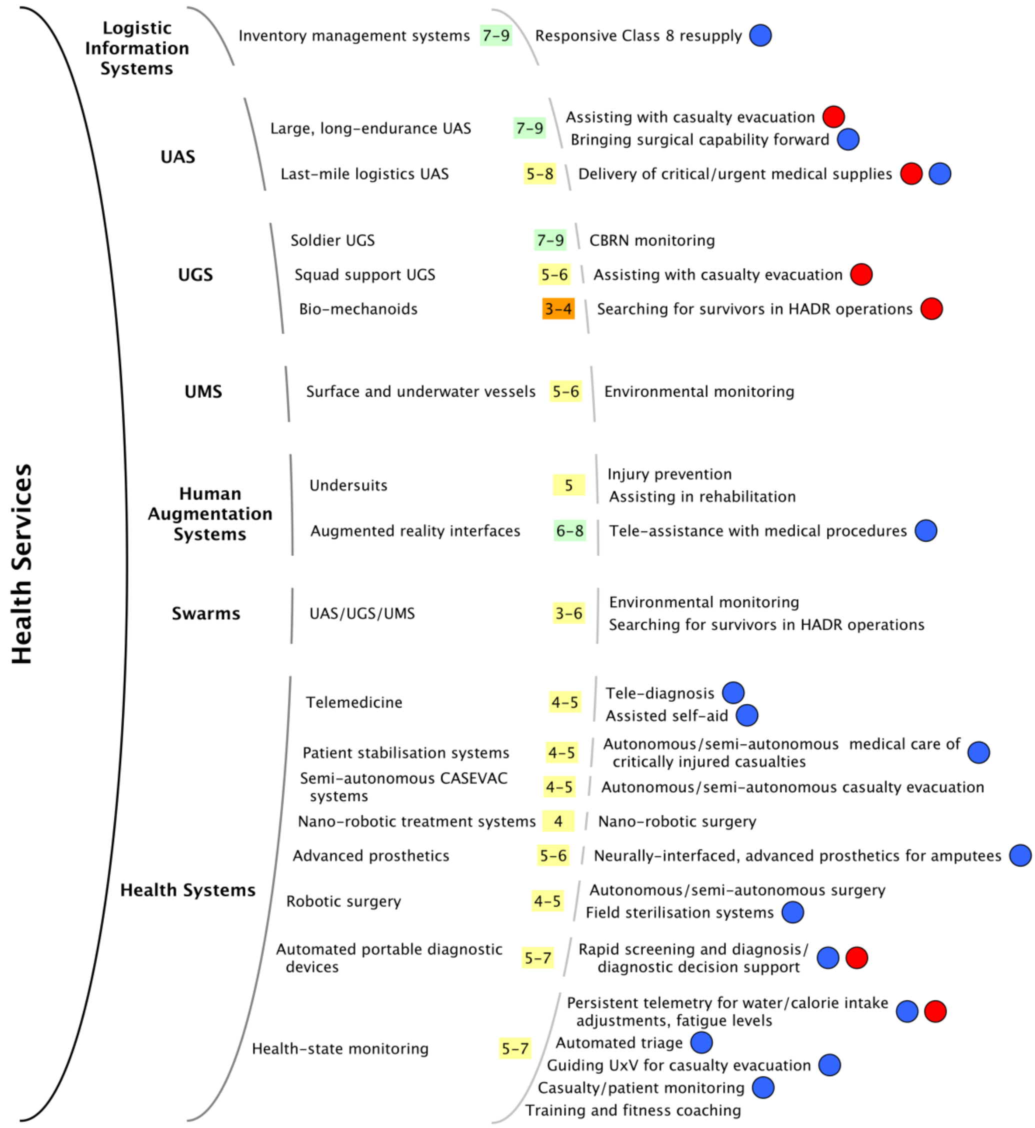

Figure 5: Applications of automated and autonomous systems for health services

2.7.4 Applications for Logistics C2 and Capability Life-Cycle Management

In terms of C2 and fleet management applications, there is considerable overlap between technology that is useful for logistic operations and that used for overarching C2 functions and strategic capability developments. Some of the more specific applications are shown in Figure 6.

Business intelligence solutions may be of use in monitoring and managing fleet expenditures. For commercial organisations, they are designed to identify areas of inefficiencies and improve overall business performance. For the military context, there may be value in the functions that allow rapid modelling of possible reactions to various events, thus facilitating better informed risk management. C2 applications for physical systems are primarily in the use of UAS for ad hoc and persistent ISR in in protection of convoys, bases and specific assets.

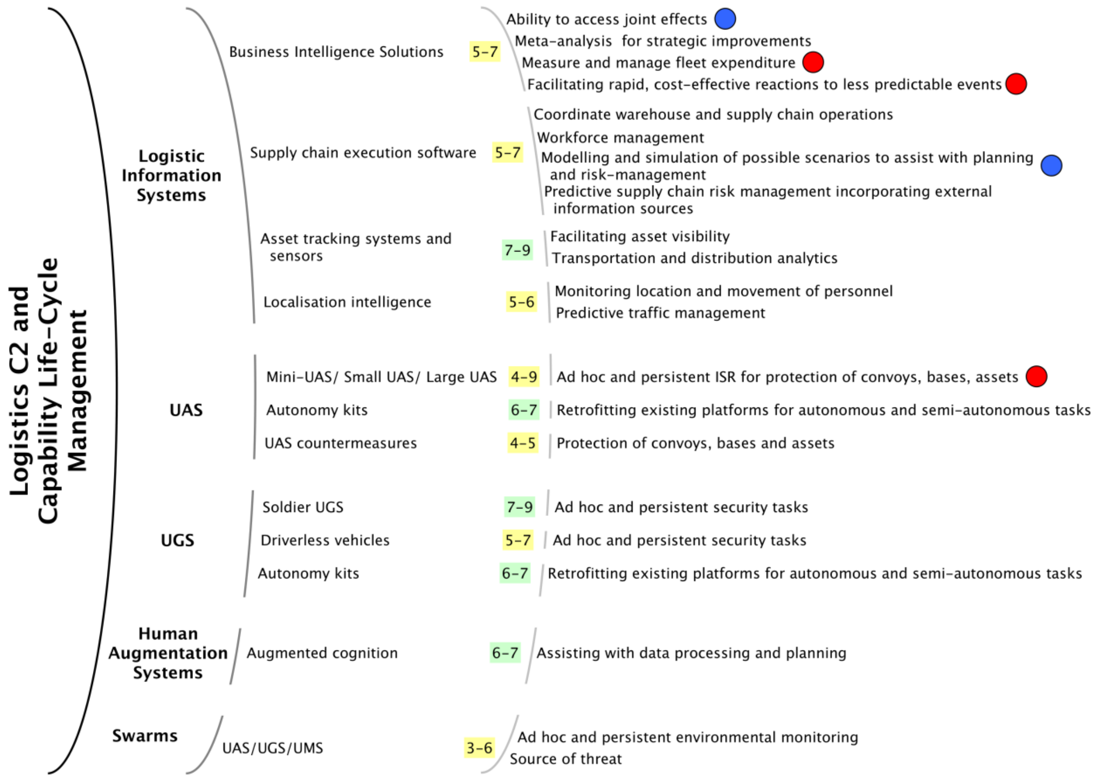

Figure 6: Applications of automated and autonomous systems for logistics C2 and capability life-cycle management

There were no overlaps for this area between the military technology reports and the SME discussions, apart from some similarity in applications relating to the use of simulation and modelling for logistics risk management and planning activities.

3. Technology Prioritisation and Information Requirements

3.1 Technology Prioritisation

Technology prioritisation was conducted to identify the technologies most relevant for the ADF Land Logistics operations. This was done in three steps:

- Initial shortlisting of nine technologies based on the review of military technology reports, discussions with ASLO Logistics Officers, and discussions with Army HQ SMEs
- Detailed discussion of each of the shortlisted technologies to determine the key arguments for and against their use for ADF Land Logistics operations
- Two iterations of voting by the Army HQ SMEs to rank the technologies in order of their relevance and significance for ADF Land Logistics operations.

The initial shortlist of technologies for consideration comprised of the following:

1. Automated, networked portable diagnostic technology for health support
2. Persistent telemetry for health-state monitoring, casualty triage, guiding evacuation platforms, patient monitoring, training and fitness coaching
3. Human augmentation – exoskeletons for material handling tasks
4. Last-mile UAS for distribution tasks and for casualty care
5. Condition-based maintenance for vehicles and key equipment
6. Predictive analytics within LIS to facilitate logistics planning and risk-management
7. Section-level load-carrying UGS
8. Semi-autonomous convoys for distribution tasks in structured and semi-structured environments
9. Precision-drop technology for distribution tasks.[14]

Table 2 outlines the key discussion points and results of two iterations of prioritisation vote that took place during the SME workshops at the Army HQ. Following a group discussion and two rounds of voting, the top three technologies to be considered for further research were:

- Predictive analytics
- Last-mile logistics UAS
- Portable networked health diagnostics.

Discussion of semi-autonomous convoys also generated considerable debate as to their applicability and flexibility for distribution tasks, but was ultimately not down-selected due to it already being addressed through other agencies.

[14] Precision-drop technology was not on the original shortlist for discussion but was added following consultation during Army HQ SME workshops.

The most significant benefits that affected the prioritisation of technologies concerned improving soldier safety, improvement of Combat Service Support (CSS) delivery and optimisation of CSS footprint. Furthermore, preference was given to the technologies that addressed particular existing problems rather than their symptoms. For example, excess load that soldiers have to carry may be alleviated through use of last-mile logistics UAS or precision air-drops. Use of exoskeletons, on the other hand, was seen as addressing the symptoms of the core problem and, therefore, not as pertinent. CBM was identified as an important technology, but already being addressed through other agencies.

The key challenges that surfaced across a number of technologies concerned the ability to understand and trust the system, potential for data overload, and data management concerns that plague networked devices: information security, data transmission capacity, data analysis support requirements, and technology integration. Furthermore, the ability of the systems to deal with complexity and adapt to changing environment were considered important, as were the logistic requirements for the systems themselves, the cost-benefit of some technologies, and the potential cultural barriers in their adoption.

Table 2: Technology prioritisation discussion points and vote counts

Technology	Arguments for use	Arguments against use	Comments	Vote 1	Vote 2[15]	Overall Ranking
Predictive analytics	• This is technology has the potential to govern how we employ all of the other technologies; it is core to CSS • Improved, more efficient supply chain operations • Optimised CSS footprint and reduced stock-piling, especially for distributed operations • Risk-management decision support tool is also needed in logistics C2 • Reduced reliance and burden on platforms • Likely to save money • For CBM, predictive analysis is needed to determine maintenance forecasting; otherwise we get scheduling confliction • Future extension to analysis of Redforce activities	• The planning functions are already being performed through current planning systems and logistic calculators • There is a risk of technology dependence • 'Garbage-In-Garbage-Out' effect and importance of high quality data • Lack of understanding of the internal workings of the decision-support/predictive analytics software and how the parameters may affect the outcome • Lack of clarity on setting constraints • SAP-type systems are restrictive and may not work in military domain; caution is required in understanding the constraints • What are the restrictions on combat teams and how adaptable is the system? • Potentially limited ability to restructure dynamically; constraints of algorithms • Potential for data overload • Cultural barriers around trust in the tools. Would the ability to use such a planning tool actually prevent stock-piling? • Information security – would it give the enemy ability to predict activities based on pre-emptive movement of supplies? • Ability to integrate with current systems • Interoperability with other countries	• Consider the use of different external intelligence feeds • This technology encompasses CBM • When used for CSS resupply planning, it may change the dynamics of 'push and pull' resupply mechanisms towards 'push'	3	5	1/1
Last-mile logistics UAS	• Reduced threat to logistics personnel; reducing targetable part of logistics • Last-mile is where logistics is most critical for the war-fighters • Reduced requirement for other technologies such as section-level UGS, or even semi-autonomous convoys • Potential to significantly reduce soldier load, e.g. with ammunition, with a rapid, reliable, trusted resupply mechanism • This technology ties in with the 'sense and respond' concept • Projecting medical capability forward is good utility of this technology; although caution is required to differentiate between projecting medical capability forward vs getting casualties out • There is back-loading potential for captured weapons, documents, etc.	• This is the hardest part of the logistic chain to get right; great level of complexity and threat • Impact on Tactics, Techniques and Procedures (TTPs) and Rules of Engagement (ROEs) • Significant risk profile – getting this wrong may mean the difference between mission success and mission failure • De-confliction of airspace • Expensive if shot down • There is relatively more redundancy in technology such as semi-autonomous convoys • Weather dependence • Human factors are important for treatment of casualties, e.g. being treated by a human, continuity of care • Cost of acquisition and maintenance • Cyber threat • Operation in contested and degraded environments: communications, GPS	• Logistics is most urgent in the 'last-mile' and it is also the most dangerous space for logisticians; logistics is often considered to be a 'soft' target • Linked technologies include semi-autonomous convoys and exoskeletons • Definition of last-mile logistics – geographic vs organisational, e.g. the last point of stores disaggregation • This approach may be revolutionary in war-fighting and logistics concepts • Doesn't have to be restricted to UAS, could incorporate UGS too	3	4	1/2

[15] In the first voting round, four participants were asked to allocate one point per technology for up to three technologies. Only three of the four participants remained for the second round. They were asked to use a 3-2-1 point allocation (three points for their top pick, two points for second best and one point for third-best pick). This allowed further differentiation between the top three technologies.

Portable networked health diagnostics	• This technology is likely to be effective • People are the most valuable asset and any improvement in treatment has to be a high priority • Reduced casualty rates • Improved casualty treatment; reduced treatment errors • Combat power effect (having too many casualties is a war-stopper) • Improvement to service • Reduced CSS footprint/ optimised CSS • Future of deployable health services/JP 2060 – realistic link for upgrades • Best practice argument: health specialists tend to come from civilian practice where they are used to using the latest technology; conversely, there may be a liability in having reservist specialists working with outdated equipment • Integration with industry and commercial sector	• Limited overall effects on the mission – this is not a critical capability • Fitness training effect only? • Other previously undiagnosed health issues may be revealed – how to select what to flag as an issue, and where is the line drawn? • Potential for data overload • Potential dependence on (wireless) communications infrastructure, hence issues around of security, and bandwidth limitations • Cyber threat, e.g. a monitoring device that can also administer medication • Privacy concerns related to collection and handling of personnel-in-confidence and medical-in-confidence information. • Integration and interoperability of systems, across levels of care, across nations in a coalition	• Link to JP 2060 • Link to persistent telemetry technology	3	4	1/2
Semi-autonomous convoys	• Optional manning gives flexibility in use of this technology • Statistically, there is a high rate of crashes due to human error; this technology would reduce this rate • Potential additional function is mapping and reporting • Optimising CSS footprint • Reduced risk to soldiers; force protection • Fuel savings • Maintenance savings • Better driving practice • Signature management – going 'air red' and being able to instantly switch off for night ops • Potential for technology transfer to other areas – combat, casualty care	• Reduced firepower increases risk to remaining soldiers • Urban environment challenges • Ability to work in degraded network space • Issue of active sensors – additional signature • Issues with ROEs, TTP (especially with weaponization) • Adaptability to changing threat environment • Additional driver tasks: loading/unloading, camouflage, dealing with small obstacles	• Different options may be used for internet/satellite communications • What are the criteria for success for the technology trials? • Applications may be extended to last-mile logistics	2	0	2/0
Precision air-drop	• Reduced requirement for other technologies such as section-level UGS • Extra delivery option to add to the current options of surface and air (rotary wing) resupply • This technology may change the way 1st, 2nd and 3rd line logistics are done with supply packs tailored at rear; ability to bypass nodes and provide faster and more tailored response • Reduced reliance on surface assets (vehicles), bypass land lines of communication (LOC) • Tactical resupply delivered by strategic asset? • Force protection effects • Improved service delivery	• Resource-intensive due to use of air-planes • Extension of tasking for limited air-asset availability • May require whole-of-force restructuring – a bridge too far? • It is difficult to get required resources for development on the smaller scale of the ADF • How can delivery be confirmed? • Reliability issues	• Consider ballistic resupply/rocket launch options and the mothership concept in re-purposing aircraft • This technology ties in with the last-mile logistics concept, but may also apply to other resupply tasks	2	0	2/0

Persistent telemetry	• Ability to monitor key parameters such as core body temperature • Improved medication management • This may align with best practice, e.g. for heat stress management; liability issues may be encountered if not using this technology in the future	• Privacy concerns related to collection and handling of personnel-in-confidence and medical-in-confidence information. • Cyber threat, e.g. a monitoring device that can also administer medication • Ability to pick up other information • Potential for data overload • Potential dependence on (wireless) communications infrastructure, hence issues around of security, and bandwidth limitations • Integration and interoperability of systems, across levels of care, across nations in a coalition • Limited understanding of this capability: what is the cost-benefit? Is it going to change behaviour? Is there use beyond training? • Cultural resistance	• Consider the pluses and minuses of constant monitoring • This technology is more relevant to the Human Performance AMLE[16] than to CSS AMLE	0	0	N/A
CBM	• Optimised maintenance based on need, not static time or usage schedules • Avoiding maintenance-induced failure	• IP ownership issues, warranty issues	• This technology is already being implemented – it's not really in the scope for the current discussion, although it's important	0	0	N/A
Section-level UGS	• Advantages of legged systems in complex terrain • Advantages of smaller and less sophisticated systems (e.g. smaller wheeled systems) for keeping soldiers out of harm's way, e.g. during bomb disposal	• Issue of cost and cost-benefit: the benefit is not there for larger, complex systems • Logistic support of the systems themselves, not least of which is the requirement for fuel/batteries for their own operation – a self-licking ice-cream • Funding issues • Recovery of such systems is a big issue, e.g. self-recovery of a legged system if its legs fail, leave them vs. destroy them? • Precision air drops and/or sophisticated and reliable last-mile logistics may mitigate the need for section-level UGS	• Example is the legged UGS like Boston Dynamics' Legged Squad Support System (LS3) (successor to Big Dog) born of a desire for US marines to have a robotic mule that can follow them anywhere over any terrain, especially that too rough for wheeled vehicles.	0	0	N/A
Exoskeletons	• Distributes materiel handling equipment (MHE) throughout the battlespace	• Cost-benefit isn't there in CSS space • For combat, this technology treats the symptom, not the problem of increasing soldier load. The focus needs to be on reducing the load. • New trucks already have loading/unloading capability	• This technology is being addressed within the Human Performance AMLE • Adoption of this technology in deployed setting may be driven by initial adoption in the rehabilitation space	0	0	N/A

[16] Army Modernisation Line of Effort (AMLE)

3.2 Technology Information Requirements and Delimiters

Further discussions during workshops with Army HQ SMEs focused on identification of key discriminators and information requirements for the technologies of interest. These are listed in the order of priority[17] below:

- Force protection
  - Frequency and level of soldier exposure
  - Impact on firepower
  - Survivability – layers of protection
  - Mobility, including protection and flexibility in culminating points
- Improvement in CSS delivery
  - Service delivery – 'right stuff, in the right place, at the right time'
  - Optimisation of CSS footprint and 'tooth-to-tail' ratio
  - Resilience, substitution opportunities, redundancy
  - Speed and accuracy
- System vulnerability
  - Capability effect of the system (e.g. skills maintenance)
  - Susceptibility to interdiction
  - Complexity (issues of transparency, trust and optimal use)
- Cost of ownership
  - Cost of development, acquisition, ownership and change
  - Maturity of technology, - are the other nations using it; has it been trialled, demonstrated and met set of user requirements
  - Cost of putting in place the Fundamental Inputs to Capability (FIC).[18] [98]

Other delimiters discussed by workshop participants included:

- Potential for extension of function, multi-tasking, and cross-domain effects
- Compatibility with current projects (especially ones with long fleet life)
- Compatibility with current capabilities and doctrine
- Relevance within the current operating concepts
- User acceptance (including cultural acceptance) and ease of use, and
- Defining the battlefield effect.

It was agreed that expecting one technology to 'win' on all the discriminators would be unreasonable. However, additional SME discussions post-workshops further identified improvement of CSS delivery/efficiency during battle as the key priority. The key discriminators to the top three technologies are summarised in Table 3. Furthermore, the participants conceded that the relevance of a technology within operating concepts should be viewed with the understanding that operating concepts are continuously refreshed and are, in turn, influenced by technology scans.

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[17] Prioritisation was conducted using a voting system similar to the one used for technologies.
[18] Fundamental Inputs to Capability include: Organisation, Command and Management, Personnel, Collective Training, Major Systems, Facilities and Training Areas, Supplies, and Support.

Table 3: Key discriminators for the top three technology picks for ADF Land Logistics operations

Technology	Prioritised discriminators
Predictive analytics	Improvement to CSS delivery Cost System vulnerability
Last-mile logistics UAS	Force protection Improvement to CSS delivery System vulnerability
Portable networked health diagnostics	Improvement to CSS delivery Force protection User acceptance

4. Detailed Use Cases for Selected Technologies

Three detailed use cases were developed prior to SME workshops and refined during the workshop discussions in order to illustrate the potential employment and use of these technologies in the theatre of operations. These use cases will be used to inform the further development of modelling and simulation pathways for technology options under the shortlisted technology areas.

The use case development process involved:

- Establishing the objective of the use case and a set of system requirements for the system (technology) in question
- Identifying relevant features and any constraints/limitations of the application of the system in the context of the use case
- Identifying the actors and stakeholders involved
- Establishing the preconditions, primary flow of actions/behaviours, and end-state of the use case, broken down into the questions of why, who, what, where and how
- Considering deviations and exceptions to the primary flow
- Generating a list of questions for further investigation/exploration, such as possible technology gaps, identifying relevant decision-making authorities/C2 structure, or implications for doctrine.

A summary of the three uses cases is presented below.

4.1 Use Case for Semi-Autonomous Convoys

This use case details a possible employment of semi-autonomous vehicles within supply convoys in theatre. Full details of the use case can be found in Appendix C.

4.1.1 Scenario

The scenario within which this use case is situated is one in which a Cavalry (CAV) regiment is due for routine resupply of classes 1, 3 and 5[19] materiel. The staging area for resupply is secure. The distribution routes are also secure but are susceptible to intermittent interdiction by light militia (1 to 3 persons). IEDs have also been used sporadically in the area.

4.1.2 Preconditions

The use case is predicated on:

- The semi-autonomous supply concept being embedded in the ADF, with the system able to be enacted as part of normal operations
- Remotely operable UAS/UGS and 'follow me' semi-autonomous assets being available for tasking
- All personnel having been appropriately trained and prepared for the use of the system
- A replenishment event occurring that is within the bounds of the system's capability.

Further, it is assumed that there are no integral weapon systems in the convoy, and that theatre experience has standardised the convoy structure to comprise two reconnaissance UAS, a remotely operated lead UGS, several semi-autonomous 'follow me' load carriers and an additional remotely operated UGS that has the capacity to assume the lead should the first UGS be compromised.

4.1.3 Use Case Narrative

The use case proceeds as follows:

1. The CAV Regiment requires administrative class 1, 3 and 5 resupply. The replenishment request is submitted and Formation-level resupply planning is undertaken. A semi-autonomous convoy from Formation stores is identified as the most appropriate means of distribution.
2. The Force Support Battalion (FSB) readies the loads and prepares the convoy.
3. For this operation, given the scenario and the security of the route, a convoy escort has been added from the requesting unit. They travel rearward to the FSB via an alternate route and rendezvous with the FSB convoy and assume command.
4. The FSB operates the convoy remotely with a rotational staff of 8 personnel, providing constant control for the 2 x UAS and 2 x UGS. The 'follow me' load vehicles lock to the lead UGS, but can be switched to an alternate lead or driven if required.

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[19] Classes of Supply: 1 – food and water; 3 – petrol (fuels), oil and lubricants; 5 – ammunition.

5. A scout vehicle from the convoy escort clears the route forward with support from the reconnaissance UAS. These are small UAS with a constant feed video link, and operated at an altitude between 3m and 50m. They are fitted with low signature equipment, and are difficult to pre-emptively detect. Two other escort vehicles provide rear and flanking support as appropriate in the terrain.
6. The convoy is engaged with small arms fire 11km short of the replenishment (Replen) point. The rear and flanking escort vehicles return fire and the lead escort vehicle and remotely operated lead UGS accelerate through the ambush. The convoy clears the ambush and continues to the Replen point. The remaining escort vehicles break contact and regain the convoy before it reaches the Replen point.
7. The CAV Regiment and Formation commander are notified of the contact. The cordon for the replenishment is extended in response, and the resupply is enacted.
8. The convoy is checked for damage and running repairs are conducted. Battery packs are changed on the UAS prior to the convoy return.
9. The convoy returns via an alternate route, again with escort, but without further incident. The ambush area is subsequently cleared by a Royal Armoured Regiment (RAR) platoon with Tank support and the route returned to secure status.

4.1.4 Questions Arising

As a summary, the set of questions arising from the use case relate to:

- The value proposition
- Asset availability
- Convoy structure and planning
    - UAS/UGS configurations and payload
    - Actions for convoy after delivery
    - Redundancy in delivery means
- Convoy protection and security
    - Weapon systems integral to autonomous convoys
    - Self-protection and defence
    - Escort requirements
    - Low detection methods to maintain security
    - Actions on contact, breakdown, obstructed route etc.
- Replenishment point and actions
    - Replen point siting and control responsibilities
    - Controls for arrival and stock transfer at Replen site
- Command, Control, Communications
    - C2 allocation, authority for asset tasking
    - Changing delivery locations/directions once deployed (also related to Technology)
- Technology
    - Vehicle range
    - Communications range, signal interference
    - Degree of autonomy embedded
    - Manual over-ride systems
    - Integration with other systems/platforms

    - Switching leader/followers
    - Cyber security, spoofing, hacking
- Legal, Doctrinal, Regulatory etc.
    - Licencing and regulatory requirements
    - Standard Operating Procedure (SOP) adjustments
    - Training and preparation of personnel
- Any conditions that preclude use
- Alternative applications for the delivery modules (e.g. decoys).

4.2 Last-Mile Logistics UAS for Combat Replenishment

This use case relates to the use of last-mile logistics UAS for combat replenishment. This refers to the tactical distribution of supplies to a dispersed force, beyond the last point of bulk disaggregation. Full details of the use case can be found in Appendix D.

4.2.1 Scenario

The scenario takes place within a contested urban environment. A RAR Infantry Section is conducting forward defence as part of a Company-level vital asset protection mission, when it comes under attack by an enemy militia. The formation retains air superiority in the area and enemy aerial fire support is not expected. However, there has been limited opportunity to stockpile ammunition in location, and the nature of the conflict restricts normal ammunition resupply.

4.2.2 Preconditions

This use case is predicated on:

- The last-mile logistics supply concept being embedded in the ADF, with the system able to be enacted as part of normal operations
- Appropriate UAS assets being available for tasking
- All personnel having been appropriately trained and prepared for the use of the system
- A distribution task being received that is within the bounds of the system's capability.

4.2.3 Use Case Narrative

The use case proceeds as follows:

1. The RAR Infantry Section is engaged by an enemy militia contingent estimated at platoon (-) size a short time after securing their position. There are no available armour assets in the vicinity, and aerial fire support is limited due to the density of the surrounding buildings and terrain.
2. The Section Commander Corporal decides to request a pre-emptive ammunition resupply and sends this through with the Contact report.

3. The S33 (staff officer responsible for the current operation) receives the contact report and hands the resupply task to the S43 (logistics officer) who engages the Combat Service Support Battalion Operations Officer (OPSO CSSB). Together they determine that immediate resupply via UAS is required. The task is authorised and the section notified.
4. The OPSO issues an immediate Warning Order (WngO). 7 minutes have elapsed.
5. The Section Second-In-Command (2IC) Lance Corporal (LCPL) secures a small emergency landing site behind a rooftop building entrance while establishing the defensive position and registers the coordinates as a contingent resupply point. He verifies the site remains secure and transmits confirmation to Company HQ and Formation HQ via radio.
6. The OPSO CSSB confirms the mission for the CSSB Warehouse platoon, confirms the route and requests air clearance through Formation HQ. Air clearance along the route to a height of 500 m is authorised through the S3 Air (staff officer air liaison).
7. The CSSB Warehouse platoon prepares two UAS with deployable packs, and dispatches them 3 minutes apart. They autonomously navigate to the resupply point along a designated route.
8. The Section 2IC LCPL activates a beacon device when the first UAS is within 200m of the resupply point, and the first UAS uses this to navigate precisely to the resupply point. It takes a low level flight path to reduce the risk of detection, and lands at the beacon 16 minutes after the resupply request.
9. The supplies are retrieved and, as there are no backload items, the UAS is released and travels back to the CSSB environs. The Section 2IC LCPL starts to distribute ammunition.
10. Three minutes later the second UAS arrives and the process is repeated. The ammunition is progressively redistributed through the Infantry Section. They are able to maintain the defensive position without casualties and the engagement ceases 29 minutes after commencement.

4.2.4 Questions Arising

As a summary, the set of questions arising from the use case relate to:

- Value proposition
    - Types of replenishment to warrant the use of a last-mile logistics distribution UAS
- Asset availability/UAS support likely to be present
- Replenishment planning
    - Redundancy in delivery means
    - Content of deployment pack
    - End user preparation prior to delivery
    - Actions for delivery module after delivery
- Asset protection and security
    - Low detection methods to maintain security
- Replenishment point and actions
    - Replen point siting and control responsibilities

  - Controls for arrival and stock transfer at Replen site
- Command, Control, Communications
  - Corps responsibilities
  - Is the asset Formation or Unit allocated?
  - Changing delivery locations, changing directions once deployed (also related to Technology)
- Technology
  - UAS range versus payload capacity
  - Communications range, signal interference
  - Cyber security, spoofing, hacking
  - Integration with other systems/platforms
  - Standardised 'delivery module' container dimensions, or specific repackaging requirements
  - Detachable or integrated UAS delivery modules
- Legal, Doctrinal, Regulatory etc.
  - Operating parameters and confines
  - Adjustments to SOPs, replenishment proformas
- Alternative applications for the delivery UAS and delivery modules (e.g. delivery of medical supplies or equipment, use of asset with a sensor payload for ISR)

4.3 Last-Mile Logistics UAS/UGS for Enhanced Battle Casualty Treatment

Closely related to the last-mile logistics distribution problem is the use of UAS (and potentially UGS) for improving the care and health outcomes of battle casualties, through:

- The rapid deployment/delivery of specialist medical equipment and supplies to battle casualties at the point of injury, prior to tactical CASEVAC
- Being a potential enabler of tele-medicine, including tele-triage and remote vital signs monitoring, using real-time audio, video and data feeds back to medical experts in a field hospital or relevant health facility.

The notion is that UAS and/or UGS could be used to push health/medical capability further forward into the battlespace, to improve care prior to evacuation to a medical facility. This use case describes one possible employment of last-mile logistics UAS for rendering such enhanced medical support. Full details of the use case can be found in Appendix E.

4.3.1 Scenario

As with the previous use case, this use case takes place in an urban setting. The general scenario comprises soldiers from a RAR Reconnaissance (Recon) Section undertaking low level reconnaissance in a constrained urban area with medium level hostilities. The section has limited integral evacuation options and compromised access to support.

4.3.2 Preconditions

The use case is predicated on:

- The enhanced system of care is embedded in the ADF and understood at each level of command, with the system able to be enacted as part of normal operations
- An embedded capability at the Field Hospital having been developed to support voice and video remote support
- All personnel having been appropriately trained and prepared for the use of the system, including an embedded staff officer with understanding of the Battle Casualty Treatment system at the Formation level HQ
- An incident occurring that has created injuries in a forward location with ADF personnel present, and that situation fitting within the operating parameters of the enhanced system of care.

4.3.3 Use Case Narrative

The use case proceeds as follows:

1. A soldier in the Recon Section trips a fragmentation IED. A suspected insurgent has been observed leaving the area to the North-West, away from the immediate location. The suspects' intentions, and any further threat that may be present, are unclear at this time.
2. The soldier sustains several fragmentation wounds to his right leg that are bleeding profusely, and less severe fragmentation wounds on his left side where debris has ricocheted off an adjacent wall. He is in extreme pain from wounds down his right side in particular, but is also reporting mid-level pain from his lower abdomen.
3. A combat medic is the first responder treating the casualty, while the Section Commander Corporal is securing the area. While there are limited integral evacuation options and a medium level of hostility, the area the casualty is in is not exposed to direct fire.
4. The Radio Operator calls for support and, in this case, bypasses Regiment HQ to the Formation as per SOPs.
5. The S33 and S43 (staff officer logistic operations) are on duty, and immediately notify the S41 (staff officer responsible for enacting and managing the combat casualty care system). The S41 verifies evacuation asset tasking and issues a WngO to the HQ Field Hospital. The S33 issues the directive to access the medical support frequency on alternate means, and further directs the Recon Section to verify status by exception, or every 20 minutes on the primary frequency. Any emergency messages from Formation HQ will be transferred via Field Hospital communications.
6. The OPSO in support of the Field Hospital notifies his staff and communicates the WngO. The OPSO Field Hospital instigates voice over casualty support from his location to the treatment site. The combat medic now conveys status and information, and his treatment is guided by the Nursing Officer/Medical Officer (NO/MO).

7. The perimeter of the secured area continues to observe sporadic fire from several locations but takes no direct engagement. The treatment area remains secure.
8. The S41 confirms the evacuation timings and determines an earliest CASEVAC of 45 minutes. The S41 authorises the deployment of medical supplies in support and the CASEVAC. 8 minutes have elapsed since the initial incident.
9. The Field Hospital Logistic team prepare a deployable supply package containing appropriate medical supplies and equipment, and dispatch it via UAS. It travels autonomously to the casualty site.
10. The Recon Section activates a beacon device when the UAS is within 200m of the resupply point, and the UAS uses this to navigate precisely to the casualty. It takes a low level flight path to reduce the risk of detection, and lands at the beacon 16 minutes after the incident.
11. The medical supplies are retrieved from the deployable pack and, in doing so, a notification is sent to the Field Hospital of successful delivery.
12. The UAS now returns to the Field Hospital location.
13. The supplies in the deployable pack are used to treat the casualty further. Included in the pack is a video link unit enabling the supporting NO/MO to now see the situation and offer additional guidance. This releases the tasking on the radio and the Recon Section returns to the primary frequency.
14. The CASEVAC arrives and takes over treatment. The casualty is transported to the next available care station as determined by the Formation HQ. It arrives 49 minutes after the incident and the soldier receives primary NO/MO care.

4.3.4 Questions Arising

The questions arising from this use case overlap strongly with the preceding one. Points of difference are largely related to the shift to a medical application include:

- Suitable medical support likely to be present
- Technology
    - NO/MO communicator platform and range/bandwidth
- Legal, Doctrinal, Regulatory etc.
    - Adjustments to SOPs, CASEVAC proformas.

5. Discussion

There is a degree of uncertainty inherent in forecasting studies, especially at a time of rapid technological development. The purpose of this study is to explore emerging technological options that may be exploited within a range of possible future scenarios. The work described in this report applies a systematic examination of the more promising technologies within an SME workshop setting. However, the technology-selection process remains a judgement-based exercise and should be treated as such. An additional level of uncertainty is introduced as the nature of warfare shifts away from the traditional understanding of battle-lines and lines of support to a more dispersed, nodal mode of operation against a protean enemy. The effects of significant technological disruptors will be to further alter the processes and targets of warfare.

In this instance, the workshop group was relatively small due to limited availability. There were five people at the start of the workshop and four people in the second half. One of the participants was from DST Group and acted mainly in an advisory role. The other participants were Army Officers working in concepts development area, projects area, and one external to logistics. There was a good range of perspectives within the workshop group, although the small number of participants can be conducive to group think in some instances. Limiting the scope of the report to the Land Logistics domain also precludes discussion of technology applications in other domains such as amphibious logistics for joint effects.

Regardless of the type of technology in question, a common area of risk can be observed in the creation of effective data management strategies. This includes data transmission, ownership, integration, storage, security, exploitation, and use for decision support. This issue is the main reason why automated and autonomous systems are not currently delivering their expected overall efficiency gains: any manpower savings in performance of an actual task are easily outweighed by the extra manpower required for data management and data analysis. Additional common areas of risk include the ability to operate in network-degraded environments, technology integration and interoperation, and trust in the technology by the operators and society at large. The latter involves consideration of the acceptable rates of failure for automated and autonomous systems.

6. Conclusion and Further Work

A wide range of automated and autonomous systems have potential uses in military Land Logistics, ranging from information systems to physical unmanned systems, and including human augmentation, health technology and management systems for power and energy. Initial indications based on literature reviews and consultations with the ADF Logistics Officers indicate that promising areas for ADF Land Logistics include:

- Use of predictive analytics to facilitate logistic planning functions and risk-management
- Use of UAS for 'last-mile' distribution tasks
- Networked portable diagnostic equipment for health support.

Higher-level information requirements for these technologies include effects on force protection, delivery of CSS, system vulnerability, cost of ownership, and organisational and technological fit. Indicative use cases for the technologies are provided within the report. The key (unresolved) issues raised through detailed examination of the use cases include:

- The 'value proposition': a need to identify the types of activities where use of A3 technology is appropriate and warranted

- Command and control: unresolved questions around asset ownership and decision-making regarding asset tasking
- Technology: communication range for remote operation/re-tasking; cyber security vulnerabilities including spoofing and hacking; standardisation of delivery modules; integration with other systems
- Asset detection and protection, including a need for redundancy in delivery means
- Flexibility: the potential for alternative use/tasking, multi-purpose asset capabilities
- Legal, doctrinal, regulatory: questions around adjustment to doctrine and SOPs.

Based on the key issues highlighted within this study, future research effort should include the following:

- Ongoing work in identifying emerging technologies and trends with further stakeholder consultation for elicitation of the most promising technology employment concepts.
- Development of a detailed research and development pathway based on the relevant metrics for CSS. This may involve qualitative and quantitative modelling and simulation, technology demonstration and pilot trials.
- Establishment of a common framework for further development of technology concepts of employment and specific use cases in order to facilitate technology assessment and sensitivity testing. These use cases can be tied in to broader scenarios applicable across a range of technologies.
- Further modelling and simulation studies based on the established metrics, methods and use cases so as to provide a solid foundation for business cases for investment in particular technologies in the future.
- Development of a detailed data management and exploitation strategy for any networked system that is selected for introduction into service, including identification of fault-tolerance levels.

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References

1. Ivanova, K. and Gallasch, G. E. (2016) *TR-LND-TP6-02-2016: Scoping Study for Use of Automated and Autonomous Systems in Land Logistics*. TTCP.
2. US DoD Defence Science Board (2012) *Task Force Report: The Role of Autonomy in DoD Systems*.
3. NATO/OTAN Allied Command Transformation *Autonomous Systems: Issues for Defence Policymakers*.
4. Crowe, K. (2015) *Use of unmanned systems by the Australian Defence Force*. Northrop Grumman Australia.
5. Klappich, D. (2014) *Hype Cycle for Supply Chain Execution Technologies, 2014*. Gartner.
6. Shaffer, A. R. (2014) *Statement testimony of Mr Alan R. Shaffer, Principal Deputy, Assistant Secretary of Defence for Defence Research and Engineering before the United States House of Representatives Committee on Armed Services, Subcommittee on Intelligence, Emerging Threats and Capabilities, March 26, 2014*.
7. TARDEC (2014) *TARDEC 30-Year Strategy Value Stream Analysis*.
8. US DoD (2013) *Unmanned Systems Integrated Roadmap FY 2013-2038*.
9. Ivanova, K. and Gallasch, G. E. (2015) *Rapid Technology Assessment Framework for Land Logistics*. General Document, Land Division, Defence Science and Technology Organisation, DSTO-GD-0870, March 2015, 75 pages.
10. Augustine, N. R. (1997) *Augustine's laws*, American Institute of Aeronautics and Austronautics.
11. Kott, A., Alberts, D., Zalman, A., Shakarian, P., Maymi, F., Wang, C. and Qu, G. (2015) *Visualising the tactical ground battlefield in the year 2050: workshop report*. US Army Research Laboratory.
12. Condon, A. (2015) Urban Combat Service Support Operations: Observations and insights from Iraq. *Australian Army Journal* **3** (3) 153-162.
13. Giesbrecht, J. (2009) *Robotics in the Army Sustain Role*. Defence R&D Canada - Suffield.
14. Sir Richard Williams Foundation (2014) *Protecting Australia with UAS*.
15. Business Wire (2015) AUVSI: Horizon unveils the world's first hydrogen powered, 4H-endurance multi-rotor UAV. *BusinessWire* Berkshire Hathaway, 05 May 2015 [Last accessed 13 January 2016]. Available from: http://www.businesswire.com/news/home/20150505005409/en/AUVSI-Horizon-Unveils-World%E2%80%99s-Hydrogen-Powered-4H-Endurance.
16. Yagdereli, E., Gemci, C. and Aktas, A. Z. (2015) A study on cyber-security of autonomous and unmanned vehicles. *Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* **12** (4) 369-381.
17. Singer, P. W. (2009) *Wired for war. The robotics revolution and conflict in the 21st century*. US, Penguin Books.
18. Bubner, N., Bubner, N., Helbig, R. and Jeske, M. (2014) *Logistics Trend Radar*. DHL Trend Research.
19. National Academy of Sciences (2014) *Force Multiplying Technologies for Logistics Support to Military Operations*. National Research Council, IBSN 978-0-309-30733-8.

20. Logivations (2015) Logistics planning and optimisation. [Last accessed 27 October 2015]. Available from: http://www.logivations.com/en/solutions/design/logistikplanung.php.
21. 'Editorial' (2014) INSIGHT - Fixing before failure: inside smart military maintenance. *Strategic Defence Intelligence*, 8 July 2014 [Last accessed 14 July 2014]. Available from: http://www.strategicdefenceintelligence.com/article/8vj4b9vkrwI/2014/07/08/insight_fixing_before_failure_inside_smart_military_maintena/.
22. General Electric (2014) *Fixing before failure: inside smart military maintenance*. [Last accessed 14 December 2015]; Available from: http://www.geautomation.com/news/fixing-before-failure-inside-smart-military-maintenance/n3105.
23. NICTA (2015) Logistics, supply chains and tranportation. [Last accessed 27 October 2015]. Available from: http://www.nicta.com.au/category/research/optimisation/projects/logistics-supply-chains-and-transportation/.
24. Maryland Robotics Center (2015) What an Upgrade! *Department of Mechanical Engineering, University of Maryland*, 31 July 2015 [Last accessed 21 September 2015]. Available from: http://enme.umd.edu/news/news_story.php?id=9186.
25. Ackerman, E. (2015) Video Friday: Tesla's Robot Tentacle, Subscale Aircraft, and Virtual Humans Getting Dressed. *IEEE Spectrum*, 7 August 2015 [Last accessed 21 September 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/video-friday-tesla-robot-tentacle.
26. Gardner, K. and Viswanath, H. (2015) S&T News Bulletin. *ASD (R&E)* **5** (33), 14 August 2015.
27. DARPA (2014) Zoom In, Zoom Out: speedy, agile UAVs envisioned for troops in urban missions. *DARPA News Release*, 22 December 2014 [Last accessed 4 May 2015]. Available from: http://www.darpa.mil/NewsEvents/Releases/2014/12/22.aspx.
28. Madrigal, A. C. (2014) Inside Google's secret drone-delivery program. *The Atlantic*, 28 August 2014 [Last accessed 28 January 2015]. Available from: http://www.theatlantic.com/technology/archive/2014/08/inside-googles-secret-drone-delivery-program/379306/?single_page=true.
29. Ackerman, E. (2014) VertiKUL UAV explores practicalities of delivery drones. *IEEE Spectrum*, 18 August 2014 [Last accessed 29 January 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/aerial-robots/vertikul-uav-explores-practicalities-of-delivery-drones.
30. Ackerman, E. (2014) Robocopters haul tons of stuff in Afghanistan, return home victorious. *IEEE Spectrum*, 31 July 2014 [Last accessed 22 January 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/military-robots/kmax-robocopters-haul-tons-of-stuff-afghanistan.
31. Royal Australian Air Force (2016) *MQ-4C Triton Unmanned Aircraft System*. [Last accessed 17 May 2016]; Available from: https://www.airforce.gov.au/Technology/Aircraft/MQ-4C-Triton-Unmanned-Aircraft-System/?RAAF-BYjCaU6eHptQ3E2EiHw9jKOLJvauES8Y.

32. Lockheed Martin Corporation (2015) *ARES*. [Last accessed 03 September 2015]; Available from: http://lockheedmartin.com/us/products/ares.html.

33. Office of Naval Research (2015) *Autonomous Aerial Cargo/Utility System Program*. [Last accessed 03 September 2015]; Available from: http://www.onr.navy.mil/en/Science-Technology/Departments/Code-35/All-Programs/aerospace-research-351/Autonomous-Aerial-Cargo-Utility-AACUS.aspx.

34. Lelinwalla, M. (2016) US Army testing more precise airdrop cargo delivery system that doesn't use GPS. *Tech Times*, 16 January 2016 [Last accessed 17 May 2016]. Available from: http://www.techtimes.com/articles/124892/20160115/u-s-army-testing-more-precise-aerial-cargo-delivery-system.htm.

35. Warwick, G. (2014) Advanced Tactic's VTOL Transformer in flight. [Last accessed 02 November 2015]. Available from: www.advancedtacticsinc.com.

36. Ackerman, E. (2015) Robotic Cockroach Launches Robotic Bird Off of Its Back. *IEEE Spectrum*, 26 May 2015 [Last accessed 16 June 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/icra-2015-robotic-cockroach-launches-robotic-bird.

37. Rogers, J. (2016) High-tech 'bazooka' fires a net to take down drones. *BGR*, 04 March 2016 [Last accessed 03 May 2016]. Available from: http://bgr.com/2016/03/04/high-tech-bazooka-fires-a-net-to-take-down-drones/.

38. Atherton, K. (2015) Israeli contractor Rafael shows off anti-drone laser in Korea. *Australian Popular Science*, 21 October 2015 [Last accessed 26 October 2015]. Available from: http://www.popsci.com.au/tech/military/israeli-contractor-rafael-shows-off-antidrone-laser-in-korea,410804.

39. Defense Advanced Research Projects Agency (2014) *Legged Squad Support System (LS3)*. DARPA Tactical Technology Office (TTO) Programmes, [Last accessed 14 July 2014]; Available from: http://www.darpa.mil/Our_Work/TTO/Programs/Legged_Squad_Support_System_(LS3).aspx.

40. Ackerman, E. (2012) DARPA LS3 Robot Mule Learns New Tricks, Loves a Mud Bath. *IEEE Spectrum*, 19 December 2012 [Last accessed 29 July 2014]. Available from: http://spectrum.ieee.org/automaton/robotics/military-robots/darpa-ls3-program-update.

41. Ackerman, E. (2013) Boston Dynamics Gets $10 Million from DARPA for New Stealthy, Bulletproof LS3. *IEEE Spectrum*, 23 September 2013 [Last accessed 29 July 2014]. Available from: http://spectrum.ieee.org/automaton/robotics/military-robots/boston-dynamics-gets-10-million-from-darpa-for-new-stealthy-bulletproof-ls3.

42. Ackerman, E. (2014) U.S. Army Considers Replacing Thousands of Soldiers With Robots. *IEEE Spectrum*, 22 January 2014 [Last accessed 14 July 2014]. Available from: http://spectrum.ieee.org/automaton/robotics/military-robots/army-considers-replacing-thousands-of-soldiers-with-robots.

43. Ackerman, E. (2014) MIT Cheetah robot bounds off tether, outdoors. *IEEE Spectrum*, 15 September 2014 [Last accessed 2 February 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/mit-cheetah-robot-bounds-off-tether-outdoors.

44. Defense Update (2011) REX, a robotic mule from IAI. 9 September 2011 [Last accessed 02 November 2015]. Available from: http://defense-update.com/20110909_meet-rex-a-robotic-mule-from-iai.html.
45. Beckman, B., Collier, J. and Giesbrecht, J. (2015) *DRDC-RDDC-2015-R: Autonomous Systems for Adaptive Dispersed Operations (Draft)*. DRDC-Suffield.
46. Metz, R. (2014) Rise of the robot security guards. *MIT Technology Review*, 13 November 2014 [Last accessed 22 January 2015]. Available from: http://www.technologyreview.com/news/532431/rise-of-the-robot-security-guards/.
47. G-NIUS Unmanned Ground Systems (2015) Guardium MK1. [Last accessed 03 November 2015]. Available from: http://g-nius.co.il/unmanned-ground-systems/guardium-ugv.html.
48. Maverick, T. (2014) New robo-trucks poised to revolutionise the mining industry. *Wall Street Daily*, 21 May 2014 [Last accessed 02 November 2015]. Available from: http://www.wallstreetdaily.com/2014/05/21/mining-robo-trucks/.
49. Torc Robotics (2015) [Last accessed 02 November 2015]. Available from: http://www.torcrobotics.com/ground-unmanned-support-surrogate.
50. Yeomans, G. (2014) *Lloyd's report. Autonomous vehicles - handing over control: opportunities and risks for insurance*.
51. *Autonomous Mobility Applique System - Lockheed Martin*. (2015), [Last accessed 22 April 2015]; Available from: http://www.lockheedmartin.com.au/us/products/amas1.html.
52. Ackerman, E. (2014) Lockheed's Robotic Trucks Pass Real-World Military Convoy Test. *IEEE Spectrum*, 12 February 2014 [Last accessed 22 April 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/military-robots/lockheeds-robotic-trucks-pass-real-world-military-convoy-test.
53. Construction Robotics (2015) *Construction Robotics - Advancing Construction | Home of the Semi-Automated Mason*. [Last accessed 26 October 2015]; Available from: http://www.construction-robotics.com/.
54. Ackerman, E. (2015) Video Friday: New Quadruped, Drone UFO, and Bricklaying Robot. *IEEE Spectrum*, 15 May 2015 [Last accessed 26 October 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/video-friday-new-hyq.
55. Gardner, K. and Viswanath, H. (2015) S&T News Bulletin. *ASD (R&E)* **5** (21), 22 May 2015.
56. Vecna (2015) *Robotics*. [Last accessed 03 September 2015]; Available from: http://www.vecna.com/rls/.
57. Short, B. (2015) *E-mail communication: FW:TTCP Spreadsheet Updates*. Personal Communication, 01 September 2015.
58. Ackerman, E. (2015) Clearpath's OTTO Robot Can Autonomously Haul a Ton of Stuff. *IEEE Spectrum*, 23 September 2015 [Last accessed 27 October 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/industrial-robots/clearpath-otto-can-autonomously-haul-a-ton-of-stuff.
59. Cockroaches fitted with microphone to aid disaster relief missions. (2014) *The Engineer*, 10 November 2014 [Last accessed 22 January 2015]. Available from: http://www.theengineer.co.uk/news/cockroaches-fitted-with-microphones-to-aid-disaster-relief-missions/1019465.article.

60. National University of Singapore (2014) New generation 'thinking' biomimetic robots developed as ocean engineering solutions. *Science Daily*, 23 December 2014 [Last accessed 4 May 2015]. Available from: www.sciencedaily.com/releases/2014/12/141223084136.htm.
61. Scharre, P. (2014) *Robotics on the battlefield Part II: the coming swarm*. Centre for a New American Security, October 2014.
62. Smalley, D. (2015) LOCUST: Autonomous, Swarming UAVs Fly into the Future. *Navy.mil*, 14 April 2015 [Last accessed 26 October 2015]. Available from: http://www.navy.mil/submit/display.asp?story_id=86558.
63. Ackerman, E. (2015) Video Friday: Robotic Kitchen, Swarming Drones, and Robots Want Your Blood. *IEEE Spectrum*, 17 April 2015 [Last accessed 26 October 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/video-friday-robot-kitchen-swarm-drones-robot-blood.
64. Gardner, K. and Viswanath, H. (2015) S&T News Bulletin. *ASD (R&E)* **5** (24), 12 June 2015.
65. Outreach@darpa.mil (2015) Friendly “Gremlins” Could Enable Cheaper, More Effective, Distributed Air Operations: Volleys of low-cost, air-retrievable, unmanned air systems promise distributed capabilities and enhanced mission effectiveness in contested environments. DARPA News and Events, 28 August 2015 [Last accessed 27 October 2015]. Available from: http://www.darpa.mil/news-events/2015-08-28.
66. Ackerman, E. (2015) DARPA Wants Swarms of Cheap “Gremlin” Drones. *IEEE Spectrum*, 1 September 2015 [Last accessed 27 October 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/aerial-robots/darpa-wants-swarms-of-cheap-gremlin-drones.
67. Lockheed Martin Corporation (2015) *FORTIS Exoskeleton - Lockeed Martin*. [Last accessed 14 December 2015]; Available from: http://www.lockheedmartin.com/us/products/exoskeleton/FORTIS.html.
68. Lockheed Martin Corporation (2014) *U.S. Navy To Test And Evaluate Lockheed Martin Industrial Exoskeletons - Lockeed Martin*. Updated 18 August 2014 [Last accessed 14 December 2015]; Available from: http://www.lockheedmartin.com/us/news/press-releases/2014/august/mfc-081814-US-Navy-To-Test-And-Evaluate.html.
69. Lockheed Martin Corporation (2015) *HULC - Lockeed Martin*. [Last accessed 14 December 2015]; Available from: http://www.lockheedmartin.com/us/products/exoskeleton/hulc.html.
70. Farmer, B. (2014) Are exoskeletons the future for the Royal Navy? *The Telegraph*, 11 September 2014 [Last accessed 28 January 2015]. Available from: http://www.telegraph.co.uk/news/worldnews/northamerica/usa/11089950/Are-exoskeletons-the-future-for-the-Royal-Navy.html.
71. The $3 million suit. Wyss Institute wins DARPA grant to further develop its Soft Exosuit. (2014) *Harvard Gazette*, 11 September 2014 [Last accessed 28 January 2015]. Available from: http://news.harvard.edu/gazette/story/2014/09/the-3-million-suit/.
72. Williams, H. (2015) This is the Australian Defence Force's Take on Exoskeleton Technology. *Gizmodo*, 21 August 2015 [Last accessed 24 November 2015]. Available

from: http://www.gizmodo.com.au/2015/08/this-is-the-australian-defence-forces-take-on-exoskeleton-technology/.

73. National Research Council of the National Academies (2009) *Opportunities in Neuroscience for Future Army Applications*. Washington D.C., USA, The National Academies Press.
74. Dorneich, M. C., Whitlow, S. D., Mathan, S., Ververs, P. M. and Sampson, J. B. (2009) *Augmented Cognition Transition*. Honeywell Aerospace Advanced Technology, produced for US Army Natick Soldier Research, Development and Engineering Center, NATICK/TR-09/015, 60 pages.
75. Levy, D. (2014) Soldier Integrated Power System CTD Succesfully Completed. *Tectonica News*, 08 September 2014 [Last accessed 24 November 2015]. Available from: http://www.tectonica.net/news/soldier-integrated-power-system-ctd-successfully-completed.
76. Office of Naval Research (2015) Autonomous Patient Care. [Last accessed 27 October 2015]. Available from: http://www.onr.navy.mil/en/Media-Center/Fact-Sheets/Autonomous-Patient-Care.aspx.
77. NATO (2012) *RTO-TR-HFM-184 - Safe Ride Standards for Casualty Evacuation Using Unmanned Aerial Vehicles*.
78. Harris, M. (2010) Battlefield Extraction-Assist Robot to ferry wounded to safety. *Gizmag*, 24 November 2010 [Last accessed 14 December 2015]. Available from: http://www.gizmag.com/battlefield-extraction-assist-robot/17059/.
79. SBIR.gov (2003) *A Robotic System for Wounded Patient Extraction and Evacuation from Hostile Environments*. [Last accessed 14 December 2015]; Available from: https://www.sbir.gov/sbirsearch/detail/93247.
80. US Department of Defence (2015) Human Performance, Training and Biosystems Directorate Newsletter, issue 3. January 2015 [Last accessed January 2015].
81. Ackerman, E. (2014) New Da Vinci Xi Surgical Robot Is Optimized for Complex Procedures. *IEEE Spectrum*, 7 April 2014 [Last accessed 10 July 2014]. Available from: http://spectrum.ieee.org/automaton/robotics/medical-robots/new-da-vinci-xi-surgical-robot.
82. ABC Adelaide (2015) Absence of surgical robot leaves new Royal Adelaide Hospital 'dumbed down', SA Opposition says. *ABC News*, 23 November 2015 [Last accessed 24 November 2015]. Available from: http://www.abc.net.au/news/2015-11-23/surgical-robot-da-vinci-needed-at-rah-opposition-says/6963392.
83. Virtual Incision Corporation (2015) *Virtual Incision Corporation*. [Last accessed 27 October 2015]; Available from: http://virtualincision.com/.
84. Ackerman, E. (2015) Video Friday: Mini Surgical Robot, Precision Drones, and Bioinspired Robotics at Harvard. *IEEE Spectrum*, 28 August 2015 [Last accessed 27 October 2015]. Available from: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/video-friday-mini-surgical-robot-precision-drones-bioinspired-robotics.
85. Gardner, K. and Viswanath, H. (2015) S&T News Bulletin. *ASD (R&E)* **5** (36), 4 September 2015.
86. VascuLogic LLC (2015) *VascuLogic | VenousPro*. [Last accessed 26 October 2015]; Available from: http://vasculogic.com/venouspro.html.
87. Gardner, K. and Viswanath, H. (2015) S&T News Bulletin. *ASD (R&E)* **5** (17), 24 April 2015.

88. Dolgin, E. (2014) Bringing HIV labs by backpack to rural Africa. *IEEE Spectrum*, 22 December 2014 [Last accessed 17 March 2015]. Available from: http://spectrum.ieee.org/biomedical/diagnostics/bringing-hiv-labs-by-backpack-to-rural-africa.
89. Strickland, E. (2015) $34 Diagnostic tool for STDs plugs in smartphone, rivals $18,000 lab equipment. *IEEE Spectrum*, 5 February 2015 [Last accessed 30 March 2015]. Available from: http://spectrum.ieee.org/tech-talk/biomedical/diagnostics/34-diagnostic-tool-for-stds-plugs-into-smartphone-rivals-18000-lab-equipment.
90. Columbia University School of Engineering and Applied Science (2015) HIV and syphilis biomarkers: smartphone, finger prick, 15 minute diagnosis. *Science Daily*, 4 February 2015 [Last accessed 10 April 2015]. Available from: www.sciencedaily.com/releases/2015/02/150204144517.htm.
91. Sensi (2015) *Diacoustic medical devices is revolutionising the future of cardiac auscultation*. [Last accessed 16 April 2015]; Available from: https://sensicardiac.com/overview.html.
92. Perry, T. (2014) Eko Devices thinks stethoscopes need a little help from the cloud. *IEEE Spectrum*, 26 September 2014 [Last accessed 2 February 2015]. Available from: http://spectrum.ieee.org/view-from-the-valley/biomedical/diagnostics/eko-devices-thinks-stethoscopes-need-a-little-help-from-the-cloud.
93. Strickland, E. (2014) At the Mayo Clinic, IBM Watson takes charge of clinical trials. *IEEE Spectrum*, 9 September 2014 [Last accessed 2 February 2015]. Available from: http://spectrum.ieee.org/tech-talk/robotics/artificial-intelligence/at-the-mayo-clinic-ibm-watson-takes-charge-of-clinical-trials.
94. Perry, T. (2014) Apple Watch's wristful of sensors and MEMS. *IEEE Spectrum*, 9 September 2014 [Last accessed 2 February 2015]. Available from: http://spectrum.ieee.org/view-from-the-valley/consumer-electronics/portable-devices/apple-watchs-wristful-of-sensors-and-mems.
95. Rijuven (2014) Rijuven News Releases: Rijuven announces Rejiva pre-orders. 1 January 2014 [Last accessed 16 April 2015]. Available from: http://rijuven.com/company.
96. Lopez, T. (2015) Army to enlist robots to pull soldiers off battlefield. *Army News*, 23 September 2015 [Last accessed 20 October 2015]. Available from: http://www.army.mil/article/155958/Army_to_enlist_robots_to_pull_Soldiers_off_battlefield/.
97. Gallasch, G. (2014) *AAA in Logistics - Notes*.
98. Australian Government Department of Defence (2014) *Defence Capability Development Manual, Part 2: Capability Development Process Guidance, Chapter 5: Fundamenal Inputs to Capability Considerations*. Capability Development Group, November 2014.
99. Scholz, J. (2015) *Trusted Autonomous Systems SRI - Program Tyche Update*. (presentation).
100. Shooter, S. (2015) *The Australian autonomy ecosystem relevant to DSTO Land Division, Version 0.8*. (unpublished)
101. University of Sydney (2015) *Australian Centre for Field Robotics*. [Last accessed 01 September 2015]; Available from: http://www.acfr.usyd.edu.au/about/index.shtml.

102. Australian National University (2015) *Welcome to the Artificial Intelligence Group*. [Last accessed 01 September 2015]; Available from: http://ai.cecs.anu.edu.au/.

103. The Hon Ian Macfarlane MP and the Hon Malcom Turnbull MP Joint Media Release (2015) CSIRO and NICTA join forces to create digital research powerhouse. 28 August 2015 [Last accessed 01 September 2015]. Available from: http://www.nicta.com.au/csiro-and-nicta-join-forces-to-create-digital-research-powerhouse/.

104. Office of Naval Research (2015) *CQ-10B Cargo UAS*. [Last accessed 02 September 2015]; Available from: http://www.onr.navy.mil/en/Media-Center/Fact-Sheets/CQ-10B-Cargo-UAS.aspx.

105. Office of Naval Research (2015) *Optimization-Based UAV Planning*. [Last accessed 02 September 2015]; Available from: http://www.onr.navy.mil/en/Media-Center/Fact-Sheets/Optimization-Based-UAV.aspx.

106. Southwest Research Institute (2015) *Unmanned Systems R&D*. [Last accessed 02 September 2015]; Available from: http://www.swri.org/4org/d10/isd/ivs/unmanned-systems.htm.

107. SoarTech (2015) *Autonomous Platforms*. [Last accessed 02 September 2015]; Available from: http://www.soartech.com/expertise/autonomous_platforms/.

108. Neya Systems (2015) *Who is Neya Systems?* , [Last accessed 02 September 2015]; Available from: http://neyasystems.com/about-us/.

109. NASA Jet Propulsion Laboratory (2015) *Mobility and Robotic Systems*. [Last accessed 02 September 2015]; Available from: http://www-robotics.jpl.nasa.gov/.

110. Lockheed Martin Corporation (2014) US Army and Lockheed Martin complete advanced autonomous convoy demonstration. 30 January 2014 [Last accessed 02 September 2015]. Available from: http://www.lockheedmartin.com.au/us/news/press-releases/2014/january/mfc-013014-us-army-lm-complete-advanced-autonomous.html.

111. US Army (2015) *Micro Autonomous Systems and Technology (MAST)*. [Last accessed 03 September 2015]; Available from: http://www.arl.army.mil/www/default.cfm?page=332.

112. TARDEC, U. A. (2014) *Ground Vehicle Robotics*. (presentation).

113. Jones, E. (2015) *E-mail communication: US Program Input*. Personal Communication, 15 September 2015.

114. ASUR (2015) *Autonomous Systems Underpinning Research (ASUR)*. [Last accessed 12 August 2015]; Available from: http://www.asur-programme.co.uk/.

115. Fry, D. (2015) *E-mail communication: 'TTCP LND TP-6 Teleconf Notes from 7 July'*. Personal Communication, 15 July 2015.

116. Roke Manor Research Limited (2014) British Army commissions Roke Manor Research to support Land Forces future capability. 09 December 2014 [Last accessed 12 August 2015]. Available from: http://www.roke.co.uk/press/20141209-techwatch.html.

117. Boukhtouta, A. (2015) *E-mail communication: RE: Teleconference Confirmation for Lin Zhang 01/09/15*. Personal Communication, 01 September 2015.

118. Boukhtouta, A. (2015) *E-mail communication: RE: Autonomy programs and initiatives table - Canada*. Personal Communication, 17 September 2015.

119. Scholz, J., Hopkin, D., Holtkamp, R., Keirl, J., Draper, M., Donnelly, B., Nothwang, W., Cannon, J. and Drobik, J. (2015) *TTCP Autonomy Strategic Challenge Group Presentation: Allied Teams Enhanced by Autonomous Machines (ATEAM)*. (presentation).
120. Skinner, M. (2014) *Overview of Autonomy Research within Aerospace Systems Effectiveness Branch*.
121. Goldsmith, K. (2015) *Conversation with Mr Kevin Goldsmith, Land Division, DST Group*. Personal Communication, 20 August 2015.

Appendix A List of Programmes and Initiatives into Automated and Autonomous Systems

Programme Name	Description	Lead Organisation(s)	Status	Point of Contact (POC)
Australia				
Trusted Autonomous Systems Strategic Research Initiative (Program Tyche)	Program Tyche has four key themes [99]: 1) 'Foundations of Autonomy' theme looks at developing and demonstrating generalizable concepts on dealing with uncertain, unpredictable and contested operational settings in order to inform strategic research direction. One of the research topics under this theme is 'Autonomous Systems for Distributed Combat Service Support', which is closely aligned to KTA 3. 2) 'Machine Cognition' theme focuses on duplicating the cognitive functions of the biological realm in the machine environment. 3) 'Trusted Partners' theme seeks to ensure that autonomous systems are never beyond meaningful control. 4) 'Novel Platforms, Sensors & Effectors' theme is about developing and integrating emerging sensors, effectors and control systems onto platforms to evaluate performance and adaptability in the context of real-world uncertainties and constraints.	DST Group JOAD, AD, MD, LD, CEWD, and NSID	Active	Jason Scholz (JOAD) is the POC for the programme overall; Lin Zhang (JOAD) and Don Gossink (JOAD) are the POC for the Autonomous Systems for Distributed Combat Service Support research project (under the Foundations of Autonomy theme)
DST Group Community of Interest in Automation, Autonomy and Autonomous Systems (A3)	A3 Community of Interest meets monthly to share information about ongoing efforts [100].	DST Group	Active	Jeffrey Tweedale
Role of Human in Autonomous Systems	The study looked at balance between human/machine capability/responsibility, definition of supervision ratios, identification of benefits and limitations of humans in autonomous systems, and identification of what human-system functions should be automated and to what extent.	DST Group LD	Finished	Vic Demczuk, Laura Carter
Australian Centre for Field Robotics (ACFR)	The Centre is dedicated to research, development, application and dissemination of autonomous and intelligent robots and systems for operation in outdoor environments. They have built working platforms for land, air and water and have worked on projects for DST Group, ADF and US DoD [100, 101].	University of Sydney, in partnership with the Australian Research Council, mining, security, defence and environmental agencies		info@acfr.usyd.edu.au Eduardo Nebot (Director), David Johnson (Research Fellow)

Artificial Intelligence Group	The Group is concerned with all aspects of artificial intelligence. It seeks to contribute to the understanding of its fundamental principles and to turn AI into an engineering discipline [102].	Australian National University (ANU)		Stephen Gould, Marcus Hutter
Autonomous Systems Laboratory (ASL)	ASL is located at the Queensland Centre for Advanced Technologies (QCAT) and operates under the Digital Productivity and Services Flagship. The group has worked with the mining industry on unmanned systems for navigation, logistics and human-robot interaction [100].	Commonwealth Science and Industry Research Organisation (CSIRO)		Elliott Duff
Data61	Recently formed digital innovation team based on the merging of CSIRO's Digital Productivity Flagship and NICTA (National ICT Australia) [103].	CSIRO/NICTA collaboration		Adrian Turner
ARC Centre of Excellence for Robotic Vision (ACRV)	ACRV is based at the Queensland University of Technology and focuses on enabling technologies of vision systems [100].	Australian Research Council (ARC)		Peter Corke
US				
CQ-10B	CQ-10B-Cargo-UAS are lightweight, inexpensive flying cargo UAS that will shortly undergo testing to characterise the flight envelope and feasibility for delivering 500 pounds cargo up to 200 miles for logistics missions. Once airborne, the system rotor turns into an autogyro, acting as the aerofoil. They can operate either autonomously or with pilot-in-the-loop Ground Control Station capabilities. The platforms can autonomously land or para-drop supply canisters [104].	US Office of Naval Research (ONR)	Active (completing efforts in 2015)	Billy Short
Hi-Speed Transporter	Previous funding by the Marine Corps Warfighting Laboratory (MCWL) resulted in development of a high speed transporter for cargo UAS missions. ONR has range and range support available from the CQ-10B flight test program to also fly the Hi Speed Transporter to explore its feasibility for logistics resupply missions.	ONR	Active	Billy Short
Aerial Reconfigurable Embedded System (ARES)	Lockheed Martin's Skunk Works is leading a team with Piasecki Aircraft to develop the next generation of compact, high-speed vertical take-off and landing (VTOL) delivery systems under the ARES programme (following on from the Transformer TX programme). This programme is approaching a flight test period late summer or early fall [32].	DARPA and Lockheed Martin	Active	Media and Press Inquiries 661-572-1130
Autonomous Aerial Cargo/Utility System (AACUS)	AACUS looks at advanced autonomous capabilities for reliable resupply/ retrograde. In the long term, the aim is to achieve casualty evacuation by unmanned air vehicle under adverse conditions. Key features of the system include autonomous obstacle avoidance while finding and landing at unprepared landing sites in dynamic conditions, with goal-directed supervisory control. AACUS technologies will be platform agnostic. AACUS Phase II has just held a flight test period [33].	ONR	Active	Max Snell (Program Officer)

Autonomous Ground Resupply	Focus of research is on robustness of the low cost perception sensors, system architecture, navigation and human robotic interaction for autonomous ground resupply technology projects [57].	ONR	Active	
Optimization-based UAV Planning	Research into optimization-based tools for optimally allocating and deploying UAVs, including selecting sensors and platforms for search and surveillance operations, allocating them to specific missions, operating the allocated sensors, and fusing information from the sensors and other sources [105].	ONR	Active	Donald Wagner
Unmanned Systems Research and Development	Research into advanced perception systems, high-performance relative and absolute localization algorithms, and application in navigation. Examples of SwRI Unmanned Systems Programs include [106]: • Mobile Autonomous Robotics Technology Initiative (MARTI®) programme • Small Unit Mobility Enhancement Technology (SUMET) • Intersection Navigation Algorithms for Automated Vehicles • Negative Obstacles Detection • Pedestrian Detection Technology • Natural Language Control of UGVs • Gesture Recognition for UGV Control • Relative and Absolute Localisation • Drive by Wire (DBW) System Analysis • Next-Gen Intelligent Transportation Systems (ITS) Technology • Active Safety and Driverless Vehicles	Southwest Research Institute (SwRI)	Active	Christopher Mentzer (Manager)
Autonomous Platforms research	Research is concerned with building intelligent, autonomous and collaborative robotic systems, including creation of autonomous platforms control architectures for single or multiple platforms, human-robot interfaces, and intelligent display of information for sharing situational awareness in team decision making [107].	Soartech	Active	info@soartech.com
Advanced unmanned systems technologies	The company works with defence, homeland security and commercial customers to deliver solutions to problems related to autonomy, computer vision and unmanned systems. Their products include: MPMS™ Advanced Mission Management for integrating multiple legacy unmanned platforms; UxFleetTM to provide fleet management for unmanned systems; UxAB™ – the next generation of rugged autonomy modules; UxSDK™ – open UAS standards; UxStreamer™ and UxStreamer™ Mini for real-time video streaming; and UxInterceptor™ UGV platform [108].	Neya Systems	Active	info@neyasystems.com

NASA Jet Propulsion Laboratory programmes	A range of programmes related to autonomy, including PIXL Optical Fiducial System, Surface Exploration Analysis and Simulation, Adaptive Resolution Stereo-Vision (ARES-V), Autonomous Small UAVs for In-situ Observation of Ecosystem Properties, Cave Robot, Wearable Interface for Natural Gesture Control and Tele-Operation of Robotic Systems, etc. [109].	NASA Jet Propulsion Laboratory (JPL)	Active	Richard Volpe (Manager)
US Army Autonomous Mobility Applique System (AMAS)	AMAS Joint Capability Technology Demonstration (JCTD) looks at development of applique for vehicles and demonstration of complex urban transit. 2014 trials conducted by TARDEC and Lockheed Martin demonstrated ability of fully autonomous convoys to operate in urban environments with multiple vehicles of different models [110].	US program with some international contributions (Australia, Japan)	Active	John Kent, Bruce J. Huffman
Micro Autonomous Systems and Technology (MAST)	Enabling research and development of transition technology to enhance soldiers' tactical situational awareness in urban and complex terrain. The focus is on enabling autonomous operation of a collaborative ensemble of multifunctional, mobile microsystems [111].	US Army Research Laboratory (ARL) with funding from DARPA, Corps of Engineers, Defence Threat Reduction Agency (DTRA) and US Navy. Integration to be conducted by BAE/JPL	Active	Brett Piekarski (Collaborative Alliance Manager)
US Autonomous Research Pilot Initiatives (ARPI)	US DoD has four technical areas of focus in autonomy: human and agent system interaction and collaboration; scalable teaming of autonomous systems; machine perception, reasoning and intelligence; and test, evaluation, validation and verification. ARPI experiment was launched in 2013 with funding for seven proposals to work on technologies on one of these four technical areas. Efforts include Autonomous Squad Member and Realising Autonomy via Intelligent Adaptive Hybrid Control [6].	US DoD	Active	
Autonomy-enabled Vehicle Capability Demonstrations (CD)	CD5: Develop unmanned vehicles capable of manoeuvring with mounted and dismounted units; CD6: Achieve ground system integrated 360^{o} situational awareness capability at extended distances from the platform IOT enhance soldier safety and ease soldier's burden; CD7: Develop robotic technologies and capabilities that expand the operational capabilities of a Brigade Combat Team; and CD12: Develop robotic technologies and capabilities that enable unit resupply and sustainment operations using optionally-manned and unmanned vehicles [112].	TARDEC Ground Vehicle Robotics/US Army RDECOM	Active	

Dismounted Soldier Autonomy Tools (DSAT)	DSAT program looks at developing a suite of autonomy tools to enable dismounted soldiers to operate unmanned vehicles. This connects with CD5 (see above) [7].	TARDEC Ground Vehicle Robotics/ (SwRI)/DCS Corporation		
Biologically inspired robots research	The Institute's strength is in designing legged robots. They have recently won the DARPA Virtual Robotics Challenge (humanoid simulation challenge) and came second in the DARPA Robotics Challenge. The group's expertise is in simulation and control of dynamic bipedal locomotion [100].	Institute for Human Machine Cognition (IHMC) Robotics Group (Pensacola, Florida) with funding from DARPA, ONR and NASA		Contact via website
Applied Robotics for Installation and Base Operations (ARIBO)	Team ARIBO focuses on use of autonomous vehicles and applications of robots at military installations. Stanford is building a simulated mock urban environment with 15 small mobile robots providing on-demand service. Stanford and West Point are piloting the Induct Navia as an automated on-demand shuttle. Ft. Bragg platforms, Star EV COTS electric vehicles will have an open, extensible architecture, leveraging TARDEC-developed autonomy hardware and software allowing for the development of modules for estimation, control and planning that can be shared with developers and research community. Inductive charging systems and fleet management tools will minimise human intervention [112].	Team ARIBO has sponsorship from TARDEC Ground Vehicle Robotics/ Stanford/ West Point/Induct/Fort Bragg WTB/ARL/GSA/ NASA/NREL		
Logistic Integration Capstone (LogIC)	Application of existing technologies to connect assets with networked sustainment systems in order to achieve process efficiencies and improved data quality. The focus is on asset visibility, currently fuel [113].	Logistics Innovation Agency (LIA)		
UK				
Autonomous Systems Underpinning Research (ASUR)	ASUR aims to develop an underpinning science and technology base to facilitate the research, development, production, deployment and operational use of intelligent unmanned systems by UK Armed Forces. The programme does not undertake fundamental research (TRL 0-1) but is concerned with research that has exploitation potential. Initial focus is on UAS. Other areas of interest include: unmanned sensor multi-layer control, optimisation and exploitation; enabling in-building operations; urban overwatch; understanding decision-making in autonomous systems; mission viability and verification, validation and accreditation of autonomous systems [114].	The programme is led by Defence Science and Technology Laboratory (DSTL) and managed by BAE Systems. The guiding consortium includes BAE Systems, Selex ES, Thales, Rolls Royce, MBDA, Roke Manor and QinetiQ	Active	Phil Brown (DSTL ASUR Technical Lead)
Platform Capabilities Emerging Technologies (PCET)	The programme looks at aids for truck drivers and support for trucks [115].	DSTL	Active	John Montgomery

Strategic Mobility Support System (STRATUS)	STRATUS programme looks at highly autonomous urban Intelligence, Surveillance, Target Acquisition & Reconnaissance (ISTAR) using a mixture of UAS/UGV concepts, with focus on novel concepts for nano-sized platforms [115].	The programme is led by DSTL and funded by Disruptive Capabilities Research	Active	Chris Jones
Emerging Technologies Working Group	Autonomy-themed emerging technologies working group held workshop on 9 July 2015 [115].	DSTL Environment Capability Board	Active	
Aerial Delivery Forum	The forum was held on 22 June 2015 and looked at the potential means of achieving logistics with more advanced systems and fewer people. Some stakeholder requirements for research into future aerial delivery systems were captured [115].	Cranfield University	Active	Ben Maddison
Unmanned Systems Project	A literature review of all various unmanned systems that might have relevance to Engineering tasks [115].	CD CSS (UK)	Active	
Science and Technology Watch Programme	Science and Technology Watch Programme aims to support the future development of Land Forces to 2030-2040. The programme starts with an 18 month research programme that will give an overview of technologies that could be exploited in the Land Environment. Robotics and autonomy is one of eleven technology groups under review [116].	DSTL has commissioned Roke Manor Research Limited to conduct the research on behalf of HQ Army	Finished	TechWatch portal info@roke.co.uk
Autonomy for Defence	To be confirmed	Defence Growth Partnership	Active	Chris Gibson (DSTL)
Additive Manufacturing & Unmanned Systems	Combining advanced manufacture with unmanned systems (either for in theatre manufacture of small unmanned platforms or just generally reducing cost and timescales of development) [115].	The programme is led by DSTL and funded by Disruptive Capabilities Research	Planning	Andrew Middleton (DSTL)
DSTL Technology Office	The global landscape of research in autonomy, quantum technologies, synthetic biology, big data and AM; results were published in 2014 [115].	DSTL Technology Office	Finished in 2014	
CD CSS Headmark Paper	The paper looks at the impact of a range of technologies covering KTAs 1-3. [115]	NITEWorks	Finished in 2015	
Canada				
Manoeuvre through Adaptive Dispersed Operations – Improved Tactical Logistics	'Improved Tactical Logistics Planning and Execution' is a Research and Development activity established to provide technical advice to the Army across the capability development process: conceive, design, build, and manage. The project looks at developing new concepts, studies and tools for integrating emerging technologies for improving in-theatre logistics [117, 118].	DRDC	Active	Jean Berger, Abdeslem Boukhtouta

Autonomous Systems for Adaptive Dispersed Operations	The goal of this project is to inform the Canadian Armed Forces of the current state of the art in unmanned systems, to evaluate the technical feasibility of their application in the future, and to provide an estimate of the level of effort required to realize their impact [118].	DRDC	Finished	Blake Beckman, Jack Collier, Jared Giesbrecht
Intelligent Logistics	Development of robotic follower capability for vehicles using both GPS and computer vision technologies, intelligent agent based logistic replenishment capabilities, real-time analysis and prioritisation of resupply in the context of current positions, projected movement and current threat analysis [118].	DRDC	Finished	Jared Giesbrecht, Greg Broten
Using small autonomous Helicopters for Logistical Resupply in Afghanistan	This activity was conducted after the decision of the Canadian Government to acquire medium or heavy lift helicopters to conduct logistical resupply missions in Afghanistan. The analysis provided preliminary answers to mainly the following question: For the same investment, can a fleet of unmanned autonomous ''Delivery Drone'' helicopters compete as logistical platforms with CH47 ''D'' Chinook along dimensions of a) economy, b) operational flexibility, and c) risk profile to both equipment and crew? [118]	DRDC-Suffield	Finished	Stephen Bogner, Dennis Fenrick
International Collaborations				
TTCP Autonomy Strategic Challenge Group (ASCG)	Defence applications areas of interest: protection, effect synchronisation, anti-fragile C2, minimisation of collateral damage, and logistic supply networks. Defence experimentation aims to demonstrate military utility and effectiveness of autonomy, and increase TRL of new technologies in littoral operations. Proposed S&T capability development areas include adversarial use of autonomy, decision software co-development and transition, science workshops on big S&T challenges, and TTCP multidisciplinary S&T team on neurobiology-inspired information processing [119]. Directly relevant area is autonomous logistic supply networks, which includes reduction of signature with smaller payloads, diversification of LOC, autonomous transport, material handling, drop-and-swap, ordering, routing, and AM for local manufacturing. Defence experimentation 2.1 (Availability) is directly relevant to autonomy in logistics. It is health-care driven, time-critical, focusing locating people and tasking first responders [119].	DST Group (AS) has lead; other participants include US, NZ, Canada and UK	Active	Jason Scholz (AS) – lead for S&T capability development
Monitoring and Controlling Multiple Assets in Complex Environments (MC-MACE)	The Project looks at enhancing the use of autonomous systems in air operations by ensuring effective human-machine teams. The research involves design, development and evaluation of new human-machine interfaces in order to improve multi-UAS control, manned-unmanned teaming, and distributed team performance involving unmanned systems [120].	Australia, Canada, UK, US collaboration	Active	Dr Michael Skinner (AD, DST Group)

TORVICE (AS/US)	Project TORVICE (Trusted Operation of Robotic Vehicles in Contested Environments) looks at operation of autonomous vehicles in contested environments, with use of cases built around logistic resupply serials [121].	DST Group / TARDEC collaboration	Active	Mr Kevin Goldsmith (LD, DST Group)

Appendix B Technology Readiness Levels

The TRL scale used in this report is based on that developed by the US Department of Defence [226], a generalised version of that originally developed by NASA [227].

1. Basic principles observed and reported. This is the lowest level of technology readiness. Scientific research begins to be translated into applied Research and Development (R&D). Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated. Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept. Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment. Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment. Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment. Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7. System prototype demonstration in an operational environment. Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an air-craft, in a vehicle, or in space).
8. Actual system completed and qualified through test and demonstration. Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to deter-mine if it meets design specifications.
9. Actual system proven through successful mission operations. Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.

Appendix C Use Case: Semi-Autonomous Convoy

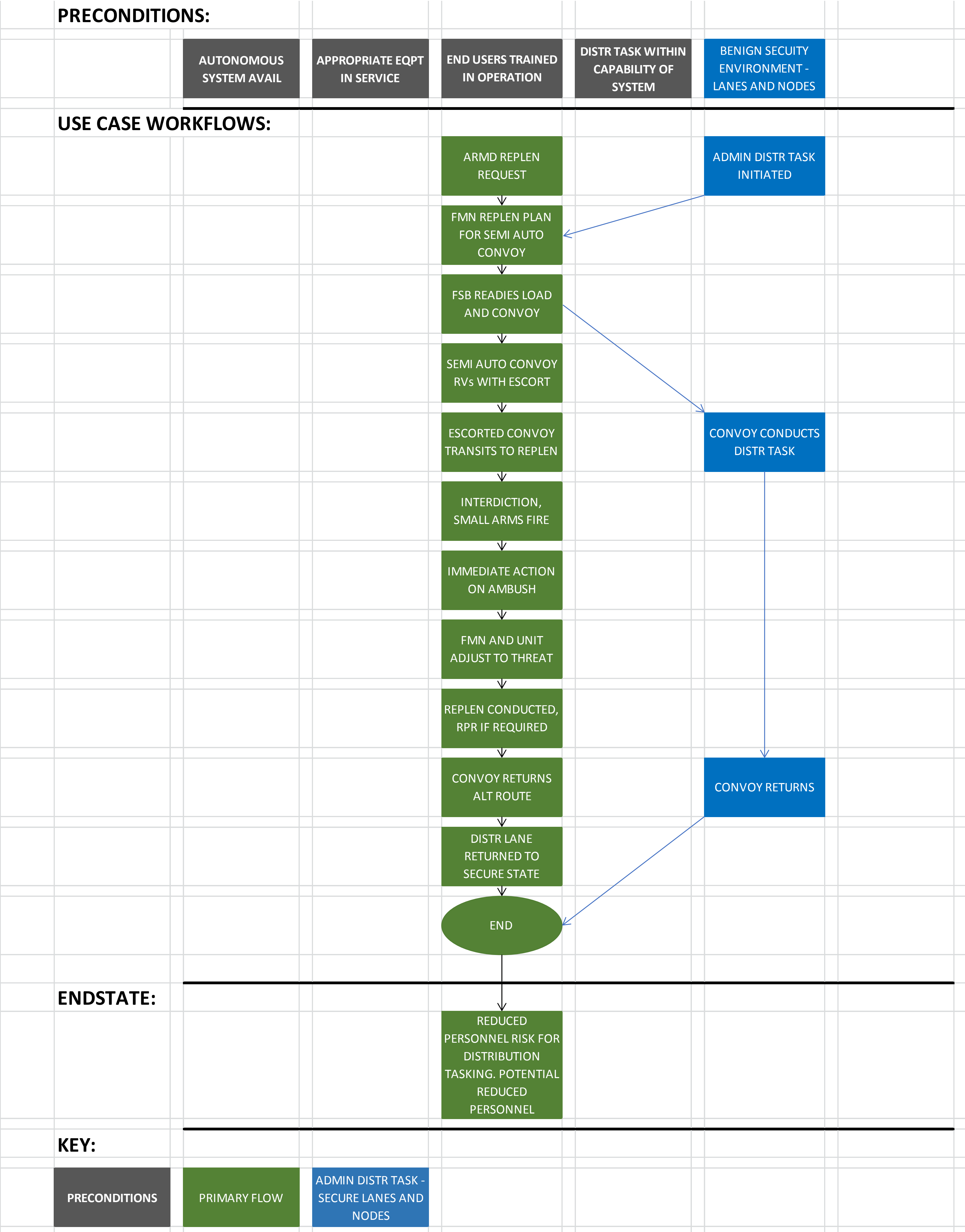
	Use Case Model - Semi Autonomous Convoy
1	**System Requirements**
1.1	The system is to reduce the physical presence of personnel required in transit for distribution tasking in opposed environments
1.2	The system needs to integrate with the current doctrinal structures of ADF distribution
1.3	The system needs to accommodate the effect of semi-autonomous and autonomous ethical issues such as any potential risk to 3rd parties or self-protection / ROE considerations
1.4	It is desirable if the system reduces the overall personnel allocation to distribution tasks

2	**Use Case Description**
2.1	**Overview**
2.1.1	The Use Case for semi-autonomous convoys has a primary flow that describes an opposed environment with low level threat in order to test the reduction of exposure to personnel
2.1.2	An extension of this premise, the introduction of higher threat levels, has not been included, but may jeopardise the desired effects. This should be included in any test case activities
2.1.3	The reduction of personnel in the convoy needs to be offset by the personnel requirement to control the convoy remotely
2.1.4	The use case includes method, agreements and processes
2.2	**Features**
2.2.1	The system shall reduce threat exposure to ADF personnel
2.2.2	The system shall compensate for the reduced convoy personnel through additional equipment available at the point of stock disaggregation (eg specific MHE, liquids transfer tooling etc)
2.2.3	The system shall consider and mitigate where appropriate, any introduced risk to any 3rd parties
2.2.4	The system shall consider and deal with any ethical consideration introduced through the removal of humans in the risk profile
2.3	**Constraints / Limitations**
2.3.1	The system shall be bound by and comply with, all legal conditions including international and domestic laws
2.3.2	The system shall ensure the security of the supported unit, and maintenance of the mission if so directed

3	**Actors and Stakeholders**	
3.1	**Actor**	**Description**
3.1.1	ADF	The ADF is the Australian Defence Force as a Defence organisation and legal entity
3.1.2	RACT	The RACT is the Royal Australian Corps of Transport with tasking to provide and control all Army owned surface transport, other than unit transport
3.1.3	Requesting Unit	The Requesting unit is any unit requiring a distribution task to be completed. This unit conveys their tactical environment for the purposes of informing the CSS unit for means selection only.
3.1.4	The CSS unit	The CSS unit is the unit providing the distribution resource to fulfill the task. It may be any line of support, but most likely the CSSB or FSB
3.1.5	Fmn HQ Comd	The Formation HQ Comd is the first command element that receives the replen request. They authorise the event and allocate the route
3.1.6	Escort	The convoy escort is a protective mobile asset supplied (in this case) by the requesting unit
3.1.7	Convoy	The Convoy is the distribution assets applied to the distribution task
3.1.8	Escorted Convoy	The escorted convoy is the combined escort and convoy, established in orders and configured in the RV point
3.1.9	Route clearance force	The route clearance force is an element designated by Fmn HQ to re-secure the route post convoy interdiction
3.1.10	Administrative requesting unit	The administrative requesting unit is unit that requires a distribution task to be enacted in a wholly secure area, including the distribution route
3.2	**Stakeholders**	**Description**
Covered by Actors		

Use Case Model - Semi Autonomous Convoy

4 Use Case Diagram



Use Case Model - Semi Autonomous Convoy

5 Use Case

5.1 Pre-conditions

	Why	Who			What	Where		How			Investigate
	Motivations	User	Actors	Owner	Needs / Aspirations	Location	Space Attributes	Method	Technologies	Services	need to check on...
5.1.1	The semi autonomous convoy concept is embedded in the ADF and understood at each level of command. All personnel are appropriately trained and the system can be enacted as part of normal operations	ADF	ADF RACT	ADF	A system that is enhanced through the application of selected technologies - namely semi autonomous movement of CSS loads in the AO in order to improve the conservation of manpower in the AO.	AS	N/A	1. Pre-agreed levels of authority to instigate and approve semi autonomous convoys 2. Clear safeguards to ensure compliance with policy 3. Well understood objectives for the system that allows adequate distribution of directive control across all levels 4. Trained and equipped CSS teams 5. Development of a semi autonomous convoy system which integrates into existing systems. This includes all aspects of FIC (fundamental inputs to capability).	Semi Autonomous delivery systems	Existing CSS framework including transport tasking and options	The structure of a semi autonomous convoy system including all process, controls, risk management protocols, organisations and personnel
5.1.2	Remote UAV / UGV and follow me vehicles available for use	ADF	ADF DMO	RACT	The capability needs to be seamlessly integrated into the existing distribution options so that any choice of employment is driven by normal factors - characteristics of method, applicability to the situation and availability. The application of this option should not be more difficult to organise or manage than any other alternate existing option			1. Determine system demands and aspects of the semi autonomous convoy system 2. Determine the most appropriate platforms for implementation 3. Understand the operating parameters, characteristics and constraints of the technology for input into training systems and use			Which platform is most appropriate? What is the value case for semi autonomous convoys? How does it integrate into the current doctrine and operating principles?
5.1.3	End users trained and prepared for use	RACT	ADF Demanding units and corps	RACT	Users, operators and planners need to understand the implications of this technology, the characteristics of its deployment, the management of it in operation and any related contingency options available to deploy the effect	In vehicle kits that allow the fleets to be adapted on command to a semi autonomous role		1. Take the platform acquisition feeds and develop training plans to implement			What are the RACT and all Corps responsibilities?
5.1.4	A distribution task has been received that fits within the confines of the Semi autonomous convoy operating parameter	Requesting Unit CSS Unit	Formation HQ	Formation HQ	A distribution task has been received that fits within the predefined constraints of the Semi Autonomous convoy system, and may generate benefit through its employment - reduced personnel risk, reduced allocation of labour etc.	Formation HQ	N/A	1. The S43 or the CSS unit OPSO has been notified of a distribution task and needs to respond. 2. The option of semi autonomous convoy is enabled and available		Formation communications system	What are the operating confines of the semi autonomous convoy system?

5.2	Primary Flow										
5.2.1	Armd replen required, semi autonomous convoy selected as distribution means										
	Semi autonomous convoy selected as distribution means for Armd replen. Escort from requesting unit required. Small arms interdiction on route. Immediate ambush drill, security re-established and replen conducted										
	Why	Who			What	Where		How			Investigate
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Method	Technologies	Services	need to check on...
5.2.1.1	An Armd administrative resupply is requested for class 1,3 and 5 in a secure staging area	Requesting unit	Fmn HQ CSS unit	CSS support unit	The requesting unit requires replen of class 1,3 and 5	Forward location Designated replen location	Secured area sufficient for replen to occur	1. Class 1, 3 and 5 consumption triggers replen requirement 2. Replen request submitted IAW SOPs		Comms network	
5.2.1.2	Fmn resupply planning is conducted and semi-autonomous convoy is selected as the distribution means. Given the security of the routes, a convoy escort is included	Fmn HQ	Fmn HQ CSS unit	Fmn HQ	A tactical replen requires interaction between the Fmn HQ and the CSS unit for authorisation, locations and routes. Detailed convoy planning, selection of convoy method and command is under the CSS support unit.	Fmn HQ CSS unit HQ	N/A	1. Tactical replen determined 2. Locations and routes selected 3. MA by CSS unit determines autonomous convoy as preferred 4. Fmn HQ confirms security environment for semi-autonomous convoy if required			Who selects semi-autonomous convoy as the distribution means? On what criteria is it selected? Are there any conditions that would preclude semi-autonomous convoy being used to satisfy the distribution task?
5.2.1.3	The CSS unit plans, prepares and issues orders for the convoy	CSS unit	Tpt element	CSS unit	Appropriate MA and operational planning to enact the distribution task	CSS unit HQ	N/A	1. CSS unit plans distribution task in detail 2. Semi-autonomous convoy approved and any additional security items authorised	Potentially UAV/UGV if not integral to the semi-autonomous convoy structure		What is the structure and optionality of semi-autonomous convoys? What additional security requirements does it need if any?
5.2.1.4	The convoy escort travels to the RV and makes contact with the convoy. The convoy escort assumes command of the convoy for movement to the replen area	Convoy	Escort Convoy	Escort	Secure RV and shake out into convoy formation	Location as per orders	Dependent on resource requirements for distribution task. May be substantial and conducted in CSS unit environs. May be a rolling RV depending on circumstances	1. RV location and timings established through orders 2. Convoy and escort move to RV point and establish contact 3. Convoy formation established and convoy leaves RV point	Follow me augmented vehicles Remote vehicles UAV/UGV as required	Comms network	Any SOP adjustments required?
5.2.1.5	The convoy commences the distribution task, moving along the route to the replen location	Escorted convoy	Escorted convoy CSS unit Fmn HQ (by exception)	Escort	Transit along designated routes to replen location. Tactical convoy movement employed	Designated routes		1. Escort in command of convoy 2. Distribution of vehicles and movement IAW tactical environment	Follow me augmented vehicles Remote vehicles UAV/UGV as required	Comms network	Apart from the convoy operation, is this the same SOPs as per current doctrine? Are there any requirements to change or adjust? Does a semi-autonomous convoy always need escort? What options if any, does the convoy have for self-protection? What would be acceptable ROE in this mode?

5.2.1.6	The convoy is engaged by small arms fire and conducts an immediate ambush drill - rear and flanking escort vehicles engage the enemy, providing covering fire for the convoy to move at speed from the area. They then break contact	Escorted convoy	Escorted convoy CSS unit Fmn HQ	Escort	Evacuate the ambush site to a safe area, resume convoy	Designated route Ambush site		1. Escort returns fire IAW LOE and notifies Fmn HQ of contact 2. Lead distribution vehicle accelerates out of ambush area (with lead escort vehicle if possible) with follow me convoy attached 3. Residual escort breaks contact and conducts rear protection 4. Contact report sent. Alternate route or orders issued to escorted convoy if required. 5. Escorted convoy continues to replen site	Follow me augmented vehicles Remote vehicles UAV/UGV as required	Comms network	What are the immediate actions on for semi-autonomous convoys? Should semi-autonomous convoys have integral firepower, and in what circumstances could it be employed? Is there a minimum security level for semi-autonomous convoys, or is it used when the security is more threatened (to meet the core objective of reducing human exposure to threat)? How else can the threat be dealt with? What is the increased threat for personnel remaining with the convoy What is the impact of additional sensors on detection and acquisition of the convoy by the enemy Can the convoy be re-tasked / redirected mid task?
5.2.1.7	Fmn HQ in conjunction with the requesting unit, assesses the action and determines that an extension of the cordon is a sufficient response to the immediate threat. Orders are issued to this effect and the requesting unit expands the cordon	Escorted convoy	Fmn HQ CSS unit	Fmn HQ	Respond to the contact IAW operational and contingency planning	Designated routes and zones		1. Fmn HQ to review contact and operational situation and respond appropriately 2. For this use case, with low threat profile and no casualties - distribution mission continued, route to be resecured, cordon to be widened		Comms network	At higher threat levels or incidents, how should the semi-autonomous convoys respond? How should the semi-autonomous convoys react to downed vehicle, casualties, obstructions etc?
5.2.1.8	The replen is conducted and any immediate repairs conducted	Escorted convoy	Escorted Convoy Requesting Unit	Requesting Unit	Replen conduct	Designated replen location within outer cordon	Dependent on task	1. RV at replen location 2. Structure to receive unit 3. Process class 1, 3 and 5 transfer 4. Evacuate replen location	Follow me augmented vehicles Remote vehicles UAV/UGV as required		What is the impact of less labour at the distribution point? Is there any additional equipment required that may compensate for the lower number of people on site?
5.2.1.9	The convoy returns by an alternate route	Escorted convoy	Escorted convoy CSS unit Fmn HQ (by exception)	Escort	Transit along designated routes to CSS unit location. Tactical convoy movement employed	Designated routes		1. Escort in command of convoy 2. Distribution of vehicles and movement IAW tactical environment 3 Transfer of command enacted on return to CSS unit environs	Follow me augmented vehicles Remote vehicles UAV/UGV as required	Comms network	Apart from the convoy operation, is this the same SOPs as per current doctrine? Are there any requirements to change or adjust? Does a semi-autonomous convoy always need escort? What options if any, does the convoy have for self-protection? What would be acceptable ROE in this mode?
5.2.1.10	The ambush area is cleared and the route security re-established	Route clearance force	Fmn HQ Route clearance force	Fmn HQ	Return route to secure IAW Fmn operational plan requirements	Designated routes		1. Allocated mission to integral f-ech unit as required			Are there any additional route clearance activities required to support semi-autonomous convoys? Is there any specific vulnerability that requires an adjustment to the route clearance process?
5.2.1.11	END										

5.3	Deviation and Exceptions										
5.3.1	Administrative distribution task for semi autonomous convoy in secured area										
	Why	Who			What	Where		How			Investigate
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Facilitation	Technologies	Services	need to check on...
5.3.1.1	A distribution task has been received that fits within the confines of the Semi-autonomous convoy operating parameter	Administrative Requesting unit	Fmn HQ CSS unit	CSS support unit	The requesting unit requires a distribution task to be completed	Secured route and delivery location		1. Distribution task requested 2. Security environment confirmed as benign 3. Distribution task commenced as per SOPs		Comms network	
5.3.1.2	CSS unit distibution task planning is conducted and semi-autonomous convoy is selected as the distribution means. Given the security of the routes, there is no requirement for dedicated convoy escort	CSS unit	Fmn HQ CSS unit	CSS unit	An administrative distribution task is likely to be planned and controlled within the CSS support unit. Fmn HQ may be informed of the resource employment and any impact to support capacity if required.	CSS unit HQ	N/A	1. Administrative distribution determined 2. Locations and routes selected 3. MA by CSS unit determines autonomous convoy as preferred 4. Fmn HQ confirms security environment for semi-autonomous convoy if required			Who selects semi-autonomous convoy as the distribution means? On what criteria is it selected? Are there any conditions that would preclude semi-autonomous convoy being used to satisfy the distribution task? In a benign security environment, is the ratio of autonomy increased?
5.3.1.3	As per 5.2.1.3. The CSS unit plans, prepares and issues orders for the convoy	As per 5.2.1.3. CSS unit	As per 5.2.1.3. Tpt element	As per 5.2.1.3. CSS unit	As per 5.2.1.3. Appropriate MA and operational planning to enact the distribution task	As per 5.2.1.3. CSS unit HQ		As per 5.2.1.3. 1. CSS unit plans distribution task in detail 2. Semi-autonomous convoy approved and any additional security items authorised	As per 5.2.1.3. Potentially UAV/UGV if not integral to the semi-autonomous convoy structure		As per 5.2.1.3. What is the structure and optionality of semi-autonomous convoys? What additional security requirements does it need if any?
5.3.1.4	The convoy commences the distribution task, moving along designated routes. This may include a pick-up and delivery task	Convoy	Convoy CSS unit	Convoy	Transit along designated routes to enact distribution task. Non-Tactical convoy movement employed	Designated routes Designated pick-up and delivery locations	Dependent on task	1. Integrated C2 in command of convoy 2. Distribution of vehicles and movement IAW security environment	Follow me augmented vehicles Remote vehicles UAV/UGV as required	Comms network	Apart from the convoy operation, is this the same SOPs as per current doctrine? Are there any requirements to change or adjust? In a benign security environment, is the ratio of autonomy increased? Is there any licencing or regulatory requirements to operate in a semi-autonomous mode?
5.3.1.5	The distribution task is conducted	Administrative Requesting unit	Convoy Administrative Requesting Unit	Convoy	Distribute goods as required	Designated routes Designated pick-up and delivery locations	Dependent on task	1. Conduct the distribution task: a. Delivery b. Pick-up and delivery c. Pick up and backload	Follow me augmented vehicles Remote vehicles UAV/UGV as required		What is the impact of less labour at the distribution point? Is there any additional equipment required that may compensate for the lower number of people on site?

5.3.1.6	The convoy returns	Convoy	Convoy CSS unit	Convoy	Transit along designated routes to enact distribution task. Non-Tactical convoy movement employed	Designated routes Designated pick-up and delivery locations	Dependent on task	1. Integrated C2 in command of convoy 2. Distribution of vehicles and movement IAW security environment	Follow me augmented vehicles Remote vehicles UAV/UGV as required	Comms network	Apart from the convoy operation, is this the same SOPs as per current doctrine? Are there any requirements to change or adjust? In a benign security environment, is the ratio of autonomy increased? Is there any licencing or regulatory requirements to operate in a semi-autonomous mode?
5.3.1.7	END										

5.4 End State (Post Conditions)

	Why	Who			What	Where		How			Investigate
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Facilitation	Technologies	Services	need to check on...
5.4.1	Enhancement of the ADF distribution system to reduce exposure of personnel to high risk environments. Potential to reduce labour required to conduct distribution tasking (with further development to autonomous platforms)	Defence	Defence Technology and Industry partners Partnering Defence organisations	Defence	Available equipment and technology, method of employment, agreements, associated FIC all in place and operating	AO, AS and administrative areas	Storage and maintenance of autonomous and semi-autonomous kits	1. Review and trials to confirm value for semi-autonomous convoys in the ADF supply chain. Assuming this is positive: 1. Establishment of technology development and acquisition program. This includes all aspects of FIC (fundamental inputs to capability) including doctrinal integration. 3. Identification of highest net benefit and prioritisation of effort. 4. Rollout and integration with current systems IAW prioritisation	Autonomous vehicles Semi-autonomous vehicles - follow me convoys, remote operation etc	Test and trial services (DSTG, CASG, End User) LEA review Defence Legal Contract management including acquisitions (CASG)	Operating concepts and doctrinal integration Value case a. Should Defence pursue semi-autonomous convoys? Liabilities and risks Defence Budget impacts

Appendix D Use Case: Last-Mile Logistics UAS for Combat Replenishment

Use Case Model - Last Mile Logistics

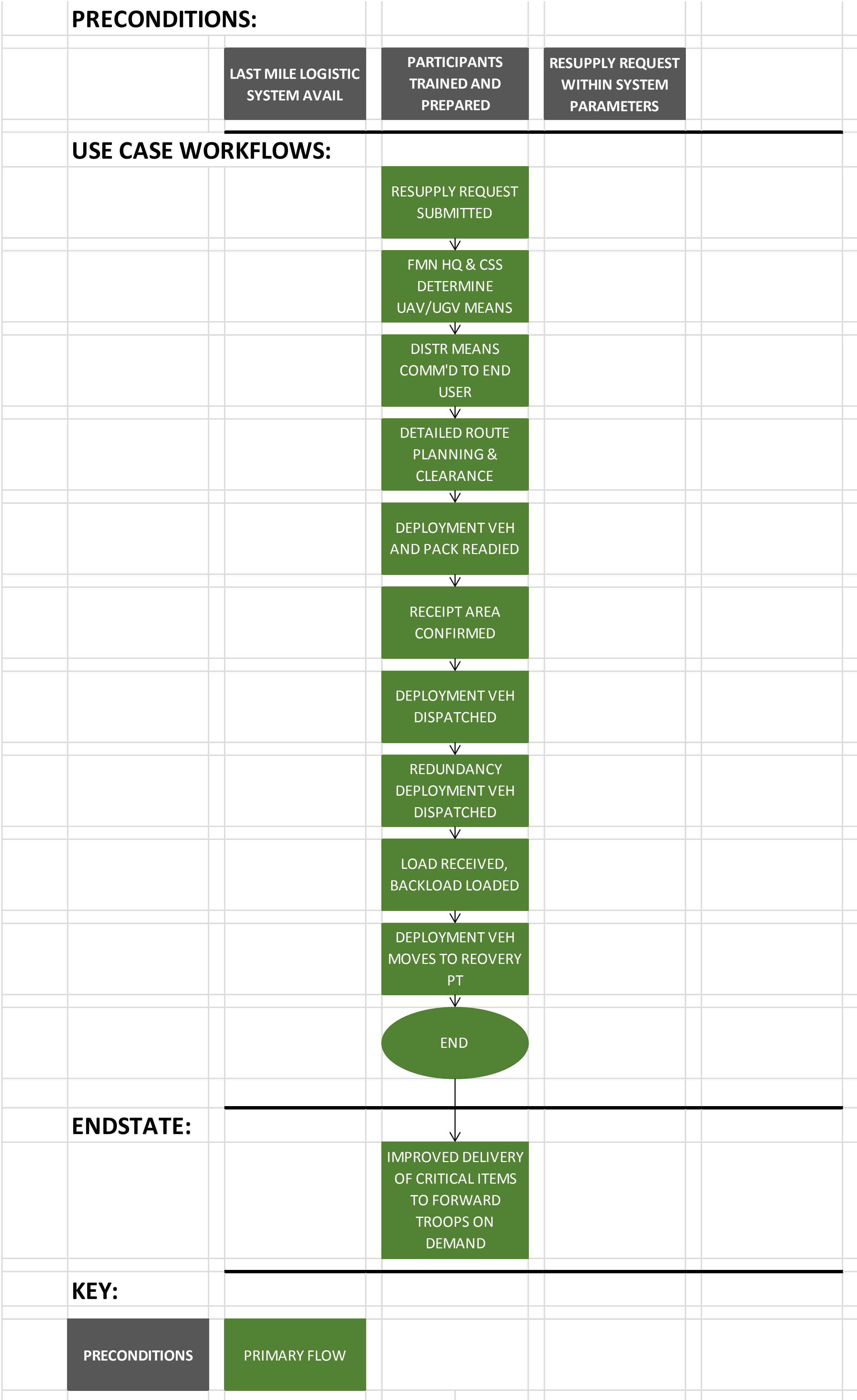
1	**System Requirements**
1.1	The system needs to satisfy a demand for a particular item in way that improves the supply of that item to the end user
1.2	The system needs to exceed in at least one characteristic compared to sourcing and supplying from other means (availability, cost, speed etc)
1.3	The system needs to integrate with the current doctrinal structures of ADF distribution
1.4	The system needs to integrate with the security environment in which it is employed, including minimising the chance of providing force disposition information to the enemy
1.5	The system needs to integrate into the current Command and Control environment
1.6	System reach needs to be determined by the capability of the tools used. Last mile logistics does not describe a limiting distance but refers instead to distribution forward of the last stock disaggregation point.

2	**Use Case Description**
2.1	**Overview**
2.1.1	The Use Case for Last Mile Logistics describes additional supply support in addition to current capability, implemented in order to improve the responsiveness and timely delivery of critical items to end users in the AO
2.1.2	The system is particularly focussed on the satisfaction of immediate demand where alternate means are compromised or are insufficient to meet the urgency of the situation
2.1.3	The Use Case assumes the Last Mile Logistics system employs scarce resources, and that these resources at times will have overloaded demand and need prioritisation
2.1.4	The use case includes method and processes
2.2	**Features**
2.2.1	The system shall provide an alternate resupply option that improves the speed of delivery for critical items
2.2.2	The system is not seen as a replacement for the CSS structure or routine supply and distribution activities currently employed. It is seen only as an augmentation
2.2.3	The system shall integrate with all current doctrine including C2 provisions, policy, doctrine and directives
2.2.4	The system is expected to be managed through the RACT as a distribution means, and enacted from stores
2.3	**Constraints / Limitations**
2.3.1	The system shall ensure the security of the supported unit, and maintenance of the mission if so directed

3	**Actors and Stakeholders**	
3.1	**Actor**	**Description**
3.1.1	ADF	The ADF is the Australian Defence Force as a Defence organisation and legal entity
3.1.2	End User	The end user is a demanding ADF unit operating in the AO. It has an operational need for a critical resupply
3.1.3	RACT	The RACT is the Royal Australian Corps of Transport with tasking to provide and control all Army owned surface transport, other than unit transport
3.1.4	Fmn HQ	The Formation HQ Comd is the first command element that receives the critical supply support request. It is the primary communications conduit for the 'End User'
3.1.5	S43	The S43 is the staff officer logistic operations on duty that receives the initial critical resupply notice.
3.1.6	CSS unit	The CSS unit is the unit providing the resource to fulfill the resupply task. It may be any line of support, but most likely the CSSB or FSB
3.1.7	CSS Warehouse Elm	The CSS warehouse element is the embedded unit responsible for preparing and dispatching in the last mile logistics system
3.1.8	S3 Air	The S3 Air is the staff officer air liaison on duty that is able to authorise air clearance for the resupply task
3.1.9	OPSO CSS unit	The OPSO CSS unit is the Operations Officer responsible for the planning and deployment of the CSS unit on behalf of the CSS Commanding Officer
3.2	**Stakeholders**	**Description**
Covered by Actors		

Use Case Model - Last Mile Logistics

4 Use Case Diagram



	Use Case Model - Last Mile Logistics										
5	Use Case										
5.1	Pre-conditions										
	Why	Who			What	Where		How			Investigate
	Motivations	User	Actors	Owner	Needs / Aspirations	Location	Space Attributes	Method	Technologies	Services	need to check on...
5.1.1	The last mile logistics concept is embedded in the ADF and understood at each level of command. All personnel are appropriately trained and the system can be enacted as part of normal operations	ADF	ADF RACT	ADF	A system that is enhanced through the application of selected technologies - namely fast response, UAS / UGS assets to deliver priority CSS loads in the AO in order to improve the timeliness for delivery of critical items	AS	N/A	1. Pre-agreed levels of authority to instigate and approve semi-autonomous convoys 2. Clear safeguards to ensure compliance with policy 3. Well understood objectives for the system that allows adequate distribution of directive control across all levels 4. Trained and equipped CSS teams 5. Development of a last mile logistics system which integrates into existing systems. This includes all aspects of FIC (fundamental inputs to capability).	Semi-Autonomous delivery systems	Existing CSS framework including transport tasking and options	The structure of a semi-autonomous convoy system including all process, controls, risk management protocols, organisations and personnel
5.1.2	End users trained and prepared for use	RACT	ADF Demanding units and corps	RACT	Users, operators and planners need to understand the implications of this technology, the characteristics of its deployment, the management of it in operation and any related contingency options available to deply the effect	AS	No change to current conditions	1. Take the platform acquisition feeds and develop training plans to implement			What are the RACT and all Corps responsibilities? Should RACT be the corps lead or is it more appropriate for RAAOC to lead?
5.1.3	A distribution task has been received that fits within the confines of the Last Mile Logistics operating parameter	End User	End User Fmn HQ	Fmn HQ	A specific need arises for an item that: 1. requires resupply in excess of the current supply chain system capacity to deliver, or 2. is easier or better to provide using the last mile logistics system	End User demand point Provisioner location Transit lanes between nodes	No change to current conditions	1. Normal use generates point demand for an item that: 1.1 cannot be supplied by normal means, or 1.2 requires resupply with a greater urgency than the system can provide, 2. This is identified and enacted by the Provisioner with guidance from Fmn HQ if required		Formation communications system	What are the operating confines of the last mile logistics system?

5.2 Primary Flow

5.2.1 Casualty incident occurs, and delivery of supplies forward with voice and video support is enacted

An incident occurs with a single military casualty, compromised access to support, a combatant first responder, restricted access to the site with limited integral evac options, with life threatening injuries and medium level of hostilities with no direct fire

	Why	Who			What	Where		How			Investigate
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Method	Technologies	Services	need to check on...
5.2.1.1	Replen request generated	End User	Fmn HQ S43	End User	A unit in the AO generates a critical resupply requirement and communicates this the Fmn HQ, most likely through a contact report	Within the AO, likely to be an opposed or semi opposed environment	N/A	1. Critical resupply required 2. Fmn HQ contacted any means 3. Resupply request transmitted		Comms network	What constitutes a critical replen that would trigger the last mile logistics system?
5.2.1.2	Autonomous replen selected as distribution method using established mission parameter rules	S43	S43 CSS unit	CSS unit	The application of the last mile logistics needs to be determined with cooperation from the Fmn HQ and the CSS unit to ensure a coordinated and aligned logistic effort, particularly if this method of replen uses rare or scarce assets	Fmn HQ CSS unit HQ	N/A	1. Replen request communicated to CSS unit 2. CSS unit determines Last Mile Logistics is preferred distribution means and conveys status to Fmn HQ 3. Fmn HQ determines forward plans are viable with Last Mile Logistics resource engaged in task and that security environment warrants this distribution means 4. Fmn HQ authorises means		Comms network	Who selects last mile logistics as the distribution means? On what criteria is it selected? Are there any conditions that would preclude the last mile logistics system being used to satisfy the distribution task?
5.2.1.3	Distribution means communicated to end user	S43	S43 End User	S43	Employment of Last Mile Logistics system conveyed to end user to allow adequate preparation to receive			1. Fmn HQ delivers SOP notification to end user		Comms network	SOP effect? Preparation steps and requirements for end user?
5.2.1.4	Detailed route planning and clearance sought	OPSO CSS Unit	OPSO CSS Unit S43 S3 Air	OPSO CSS Unit	The OPSO CSS plans out the most appropriate route in conjunction with the S43. The deployment vehicle requires air or route clearance. For UAS this is submitted to the S3 Air, for ground the S43 is able to authorise. This clearance is then issued	Fmn HQ CSS unit HQ	N/A	1. Existing route restrictions considered 2. Route plan developed 3. Air or ground clearance sought 4. Air or ground clearance received		Comms network	Clearance procedures for UAV / UGV SOP requirements
5.2.1.5	Deployment pack readied and deployment vehicle (UAV / UGV) loaded	CSS Warehouse elm	CSS Unit CSS Warehouse elm	CSS unit	The deployment pack is ideally prepared in advance but may have additional items to load. It needs to be checked and prep'd for delivery to ensure safe transit of its' contents	CSS Warehouse elm environs	Storage and prep areas	1. The CSS OPSO issues the support directive as per SOPs 2. The warehouse team verifies the order, locates and selects the appropriate deployable pack, and conducts final checks and packing		SOPs Standard packing system?	What is the structure and optionality of the last mile logistics system? What additional security requirements does it need if any? Should there be standard packs and standard uses for the last mile logistics systems, or should they be bespoke according to the need?

5.2.1.6	Localised receipt area identified and confirmed	End User	End User Fmn HQ CSS unit	End User	The end user needs to confirm that they have the location and means to receive the delivery effectively, or advise to allow the system to investigate other options	End user location	Beacon point (if selected method of guidance) Secure area to unload deployment vehicle Clear lanes of approach to support distribution success	1. End user conducts hasty recon and advises Fmn HQ of outcome		SOPs	Any priority info requirements? How is the receiving area set up, what characteristics does it need, what SOPs does it need?
5.2.1.7	Deployment Vehicle dispatched	CSS Warehouse elm	S3 Air CSS Unit CSS Warehouse elm	CSS unit	The deployment vehicle is released and transits to the resupply location. Its route and the characteristics of its travel need to be consistent with the security environment and threats. It may be remotely controlled, autonomous or a combination of both. The S3 Air is notified of the release	Ground or air transit lanes		1. OPSO CSS unit request ground or air clearance for the UAV or UGV. 2. The S3 Air or S4 (depending on Air or Ground route clearance) issues clearance as per SOPs 3. The OPSO CSS Unit directs the deployment of the UAV or UGV to the resupply site. This may be either remote operation or autonomous transport 4. The deployable pack is deposited in the resupply area	UAV / UGV distribution systems	Air clearance or route clearance system as required	Clearance procedures for UAV / UGV Possible dedicated UAV / UGV pre-allocated corridors Navigation tooling and resources for UAV / UGV Low detection aspects to retain security for forward troops
5.2.1.8	Redundant delivery means readied and dispatched (if req'd)	CSS Warehouse elm	CSS Unit CSS Warehouse elm	CSS unit	Depending on the security environment and the criticality of demand, alternate distribution needs to be enacted to ensure successful delivery. This may include secondary loads, means or routes to overcome the threat overlay	Ground or air transit lanes		1. CSS unit and Fmn HQ determine requirement for redundant distribution 2. OPSO CSS unit request ground or air clearance for redundant transport system. 3. The S3 issues clearance as per SOPs 3. The OPSO CSS Unit directs the deployment of the redundant distribution to the resupply site. This may be either manual, remote operation or autonomous transport 4. The supplies are deposited in the resupply area	UAV / UGV distribution systems		Redundancy requirements in distribution
5.2.1.9	Localised beacon activated to guide deployment vehicle to receipt area	End User	End User	End User	Depending on the delivery means, a method of guiding the supplies to the receipt point is required. This may be detailed grid reference, beacon, remote operation or some other signalling process	Receipt area and approaches		1. Receive indication of imminent arrival - comms or visual 2. Activate signalling device	Signalling device UAV / UGV distribution systems		Method to positively locate receipt location for delivery? Is there a way to wave off the UAV / UGV, delay delivery, or adjust delivery point once it is deployed? Should there be a primary and secondary option for this instruction to the UAV / UGV?

5.2.1.10	Replen arrives, load received, backload items loaded, deployment vehicle released	End User	End User	End User	Unloading of supplies for immediate use. Loading of any backload conducted - this may include seized intel items such as documents, phones, laptops etc	Receipt point		1. The deployable pack arrives in location 2. The end user detaches the deployable pack and accesses the supplies. 3. The end user then activates a response to the CSS Unit acknowledging receipt 4. Any redundant deployment packs in transit are potentially turned around 5. Backload items are loaded for the return transit (if req'd)	UAV / UGV distribution systems		Packaging requirements Does the UAV/UGV land or drop? Response mechanism to acknowledge receipt Messaging to control movement once deployed (and change delivery locations) Detachment mechanism to minimise time accessing supplies Possible packing order to reflect treatment process? Low detection delivery means into treatment area
5.2.1.11	Deployment vehicle moves to recovery point	End User	UAV/UGV asset	CSS unit	Deployment vehicle returns to a recovery point. This may be forward of the CSS to extend the reach of the system	Recovery point (may be outside of the CSS environs to extend the delivery range)		1. Return route either pre-programmed or directed on release 2. UGV / UAV travels as per direction 3. UGV / UAV backloaded as appropriate			How to direct return Backloading protocols
5.2.1.12	END										
5.3	**Deviation and Exceptions**										
None specified											
5.4	**End State (Post Conditions)**										
	Why	**Who**			**What**	**Where**		**How**			**Investigate**
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Facilitation	Technologies	Services	need to check on...
5.4.1	Enhancement of the ADF distribution system to improve the speed and responsiveness of critical item delivery within the AO, primarily to forward units	Defence	Defence Technology and Industry Partners Partnering Defence Organisations	Defence	Available equipment and technology, method of employment, agreements, associated FIC all in place and operating	AO, AS and administrative areas	Storage and maintenance of deployment packs and vehicles	1. Develop operating concept and model effect of a Last Mile Logistics system to determine likely value and employment 2. Select shortlist of technologies and conduct trials as appropriate. Assuming this is positive: 3. Establishment of technology development and acquisition program. This includes all aspects of FIC (fundamental inputs to capability) including doctrinal integration. 4. Identification of highest net benefit and prioritisation of effort. 5. Rollout and integration with current systems IAW prioritisation	UAS UGS Packaging	Test and trial services (DSTG, CASG, End User) LEA review Defence Legal Contract management including acquisitions (CASG)	Operating concepts and doctrinal integration Value case a. Should Defence pursue last mile logistics? Liabilities and risks Defence Budget impacts

Appendix E Last-Mile Logistics UAS/UGS for Enhanced Battlefield Casualty Treatment

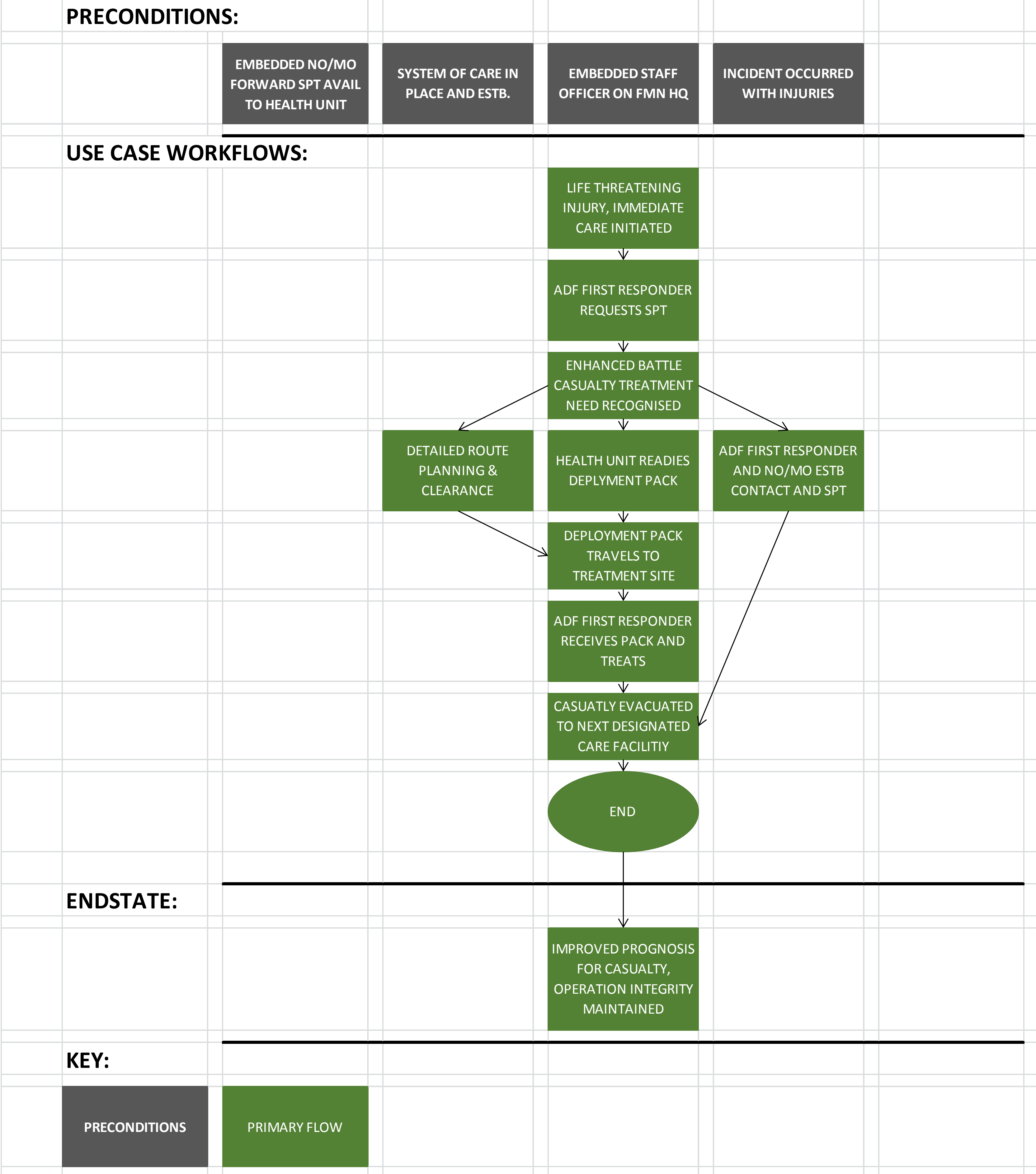
	Use Case Model - Enhanced Battle Casualty Treatment (UAS/UGS)
1	**System Requirements**
1.1	The system is to improve combat casualty care in order to improve the likelihood and extent of injury recovery
1.2	The system needs to integrate into the current Command and Control environment
1.3	The system needs to integrate into the existing medical care strategy for Defence and ADF
1.4	The care provided needs to be in accordance with accepted medical practice, including skills and expertise of treating responders
1.5	The system needs to retain the human element of casualty care and treatment
1.6	The system needs to deliver support prior to the arrival of CASEVAC assets to provide enhanced support

2	**Description**
2.1	**Overview**
2.1.1	The Use Case for Enhanced Battle Casualty Treatment describes additional support services to improve survivability and prognosis after injury within the AO.
2.1.2	The system is particularly focused on providing enhanced services from the time of occurrence to the application of the next level of care (which may be through evacuation)
2.1.3	The system is expected to improve healthcare through faster access to supplementary supplies and equipment, and access to medical advice at the point of occurrence
2.1.4	The use case includes method, agreements and processes
2.2	**Features**
2.2.1	The system shall improve the supplies and equipment at the point of injury occurrence, and during any evacuation required
2.2.2	The system shall allow tele interaction with forward responders to expand the provision of medical advice and support throughout the AO
2.2.3	The system shall comply with sound medical practice and all policy, procedures and directives extant in the RAAMC
2.2.4	The system shall improve the likelihood and extent of recovery for any casualty treated
2.3	**Constraints / Limitations**
2.3.1	The system shall be bound by and comply with, all legal conditions including international and domestic laws
2.3.2	The system shall ensure the security of the supported unit, and maintenance of the mission if so directed

3	Actors and Stakeholders	
3.1	**Actor**	**Description**
3.1.1	ADF	The ADF is the Australian Defence Force as a Defence organisation and legal entity
3.1.2	RAAMC	The RAAMC is the Royal Australian Army Medical Corps with tasking to conserve manpower through the application of health services
3.1.3	Casualty	The casualty is an injured person needing support from the ADF casualty care system
3.1.4	ADF First Responder	The ADF first responder is the first ADF personnel on the scene that renders assistance to the casualty. It may be 1 or more people, a fellow combatant or a trained medic
3.1.5	Fmn HQ Comd	The Formation HQ Comd is the first command element that receives the initial casualty support request. It is the primary communications conduit for the ADF first responder
3.1.6	S4	The S4 is the senior staff officer on the formation HQ that is responsible to the Fmn Comdr for all logistic effort, including health services
3.1.7	S43	The S43 is the staff officer logistic operations on duty that receives the initial CASEVAC notice. They may also be the Formation S41
3.1.8	S41	The S41 is the staff officer on the Formation HQ responsible for enacting and managing the combat casualty care system on behalf of the formation commander
3.1.9	Unit HQ	The Unit HQ is the regimental or company HQ responsible for the casualty or ADF first responder
3.1.10	Supporting Health Unit	The supporting health unit is the organisation responsible to deliver health services to the formation. It is likely to be an R2E or R2LM facility under current doctrine, but may be adjusted to suit the operation
3.1.11	OPSO Health Unit	The OPSO health unit is the Operations Officer accountable for the Field Hospital asset on behalf of the CO Field Hospital
3.1.12	Forward Casualty Support Personnel	The forward casualty support personnel may be an individual allocated to the task, or a team depending on the need. They provide enhanced Battle Casualty Treatment through voice and video support to the ADF first responder. They may have a Comms Tech under command for this task. While not employed with Enhanced Battle Casualty Care voice and video support, it is expected that they would contribute to the normal health support mission of the Health Unit. Alternatively, they may be based out of the AO
3.1.13	Field Health Unit Logistics Team	The field hospital logistics team manages, coordinates and directs the storage and distribution of the Enhanced Battle Casualty Care deployment packs. This may be a centralised team under an alternate comd, or integral to the Health Unit
3.1.14	S3	The S3 is the senior staff officer on the formation HQ that is responsible to the Fmn Comdr for current operations, and can issue clearance through the AO for UAVs or UGVs
3.1.15	NO/MO	The NO/MO is the medically trained person that provides voice or video support to ADF first responder in the treatment area. They are included as key personnel in the 'forward casualty support personnel'
3.2	**Stakeholder**	**Description**
Covered by Actors		

Use Case Model - Enhanced Battle Casualty Treatment (UAS/UGS)

4 Use Case Diagram



	Use Case Model - Enhanced Battle Casualty Treatment (UAS / UGS)									
5	Use Case									
5.1	Pre-conditions									
	Why	Who			What	Where		How			Investigate
	Motivations	User	Actors	Owner	Needs / Aspirations	Location	Space Attributes	Method	Technologies	Services	need to check on...
5.1.1	The enhanced system of care is embedded in the ADF and understood at each level of command. All personnel are appropriately trained and the system can be enacted as part of normal operations	ADF	ADF RAAMC	ADF	A system that is enhanced through the application of selected technologies - namely autonomous delivery of forward supplies and comms links to NO / MO personnel - in order to improve the conservation of manpower in the AO while also considering risk. In particular - casualty survival, safety for first responders and evacuation teams and economics of technology enhancements	AS	N/A	1. Pre-agreed levels of authority to instigate and approve casualty treatment options 2. Clear safeguards to ensure compliance with policy 3. Well understood objectives for the system that allows adequate distribution of directive control across all levels 4. A trained and equipped forward casualty support team 5. Development of an enhanced Battle Casualty Treatment system which integrates into existing systems. This includes all aspects of FIC (fundamental inputs to capability).	Autonomous delivery systems Enhanced voice and video link equipment	Existing Battle Casualty Treatment system including CASEVAC procedures	An enhanced battle casualty treatment system including all process, controls, risk management protocols, organisations and personnel
5.1.2	An embedded capability at the Field Hosp is developed to support voice and video remote support	ADF first responder	NO/MO OPSO Health Unit	OPSO Health Unit	The capacity needs to be activated at short notice at any time, and consists of medically trained personnel to render voice and video support to the ADF first responder in the treatment area. The aim is to improve the level of care in the early period post incident in order to improve survivability and prognosis	Field Hosp environs	Dedicated space with appropriate voice and video technology	1. Determine system demands and aspects of the enhanced Battle Casualty Treatment system 2. Determine if the skills base and resources required to deliver the forward casualty support team function are present or need to be developed 3. Conduct training to allow additional duties to be taken up, or create an appropriate new FTE structure and fill positions as appropriate	Voice or video means		Requirements of forward casualty support team as part of the enhanced battle casualty treatment system Check location of medical UAV - dedicated unit or adhoc. If adhoc, what is the effect of transit time to load etc?
5.1.3	An embedded staff officer with understanding of the Battle Casualty Treatment system at the formation level HQ	Formation HQ	Formation HQ Allocated Health Unit	Formation HQ	The HQ needs to be able to deploy the alternate Battle Casualty Treatment responses and liaise with the allocated Health Unit support. This is likely to be an augmentation to the S41 responsibilities, but may require a dedicated RAAMC Ops Officer to be attached	Co-located at Formation HQ	Work space as for other staff officers	1. Determine system demands and aspects of the enhanced Battle Casualty Treatment system 2. Determine if these responsibilities can be completed through the existing S41 staff officer role 3. Conduct training to allow additional duties to be taken up, or create an appropriate new FTE and fill the position as appropriate	N/A	N/A	Additional aspects to control within the S41 responsibilities

5.1.4	An incident has occurred that has created injuries in a forward location with ADF personnel present, and the situation fits within the operating parameters of the enhanced system of care	Casualty ADF first responder	Formation HQ	Formation HQ	An incident with casualties has occurred and an ADF first responder is on the scene. They are able to access the Battalion Aid station and have support from a trained medic. The formation HQ has been notified. The S41 has the option to CASEVAC as per current process, or to engage augmentation through the enhanced Battle Casualty Treatment system	Formation HQ	N/A	1. The S41 (or HQ RAAMC Ops Officer) has been notified of a casualty situation and needs to respond. 2. The option of CASEVAC is enabled, and the option of enhanced forward care is available		Formation communications system	
5.2	**Primary Flow**										
5.2.1	**Casualty incident occurs, and delivery of supplies forward with voice and video support is enacted**										
	An incident occurs with a single military casualty, compromised access to support, a combatant first responder, restricted access to the site with limited integral evac options, with life threatening injuries and medium level of hostilities with no direct fire										
	Why	**Who**			**What**	**Where**		**How**			**Investigate**
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Method	Technologies	Services	need to check on...
5.2.1.1	A life threatening injury is incurred by a soldier in a deployed unit. They are removed from the direct combat area if applicable, and are in an area under threat, but with no direct fire. The ADF first responder needs to render immediate care and access support	Casualty ADF first responder	Casualty ADF first responder	ADF First responder	The ADF first responder needs to render immediate care and access support	An area under threat, but with no direct fire. This location is yet to be communicated to any support asset	Situational	1. ADF first responder removes casualty from immediate combat area if required 2. A treatment location is established as the situation dictates 3. The ADF first responder renders immediate care to the limit of their skills and supplies, this includes the support of a fully trained medic for this scenario	N/A	Unit level Immediate Action drills	The likelihood of a medic presence, and any adjustments needed if this is not likely or available
5.2.1.2	The ADF first responder needs support to effectively treat the casualty and contacts their higher command. They convey the situation via radio	ADF first responder	ADF first responder Fmn HQ Comd S43 S41 Unit HQ	S4	The S41 needs sufficient information from the first responder to adequately react to the occurrence	The treatment area Formation HQ	Within existing structures	1. The ADF first responder initiates CASEVAC procedures as per SOP. 2. The CASEVAC message is conveyed to the formation HQ 3. The S43 reviews the message and engages the S41 as appropriate	Formation comms system	SOPs	Are there any adjustments to the CASEVAC proformas or standard messaging

5.2.1.3	The S41/S43 recognises the need for enhanced Battle Casualty Treatment and initiates support.	S43 S41	S43 S41 Supporting Health Unit	S4	The conditions present mean that the Battle Casualty Treatment can improve the prognosis for the casualty. It will provide some improvement in the level of medical care available whilst evacuation is arranged	Formation HQ	N/A	1. The S41 is aware of asset restrictions and understands the current expected dwell time for the casualty 2. The S41 is aware of the Battle Casualty Treatment asset, and has units available 3. The S41 issues the order for the Battle Casualty Treatment asset to be deployed 4. The availability of sufficient comms equipment is verified, and the S41 then authorises the Battle Casualty Treatment radio frequency for immediate support. (If there is not sufficient comms equipment for a dedicated service, then this aspect may not be implemented)	Formation comms system Dedicated medical comms system Enhanced Battle Casualty Treatment deployment pack Enhanced Battle Casualty Treatment delivery module Enhanced Battle Casualty Treatment communicator	Forward Casualty Support Personnel	Dedicated medical comms frequencies and bandwidth Contents of deployment pack Enhanced Battle Casualty Treatment delivery module - UAV or UGV, capability determination needed Enhanced Battle Casualty Treatment communicator - capability determination needed Security implications Forward Casualty Support Personnel configuration, training and capability mix Is air superiority relevant to the decision of whether to deploy UAVs or not?
5.2.1.4	Detailed route planning and clearance sought. Concurrent with 1.2.1.5 and 1.2.1.6	OPSO Health Unit	OPSO Health Unit S43 S3 Air	OPSO Health Unit	The OPSO Health Unit plans out the most appropriate route in conjunction with the S43. The deployment vehicle requires air or route clearance. For UAS this is submitted to the S3 Air, for ground the S43 is able to authorise. This clearance is then issued	Fmn HQ Health unit HQ	N/A	1. Existing route restrictions considered 2. Route plan developed 3. Air or ground clearance sought 4. Air or ground clearance received		Comms network	Clearance procedures for UAV / UGV SOP requirements
5.2.1.5	Assuming there is sufficient comms equipment to maintain a dedicated line to the ADF first responder and casualty, the Health Unit remote team makes contact with the first responder and renders voice support. Concurrent with 1.2.1.4 and 1.2.1.6	ADF first responder	ADF first responder S41 OPSO Health Unit Forward Casualty Support Personnel	OPSO Health Unit	The ADF first responder gets direct communications with a qualified NO/MO through comms with the Field Hospital remote support team.	Dedicated location at the Field Hospital The treatment area	Within existing structures	1. The OPSO issues the support directive as per SOPs while the S41 rep notifies the ADF first responder to change frequencies as per SOPs 2. The field hospital remote support team is assembled as the comms Tech makes contact with the ADF first responder 3. The field hospital remote support team provides support as required	Dedicated medical comms system	Forward Casualty Support Personnel SOPs	SOP for support directive - ADF first responder to change frequencies and radio check, field hospital to assemble team and establish support Protocol for comms use, frequency switching etc
5.2.1.6	The Health Unit readies the deployment pack and delivery means. Concurrent with 1.2.1.4 and 1.2.1.5	Health Unit Logistics Team	OPSO Health Unit Field Hospital Logistics Team	OPSO Health Unit	The deployment pack is ideally pre-prepared but may have some additional items to load. It needs to be checked and prepped for delivery to ensure that its contents can best help the ADF first responder treat the casualty	Field Hospital environs	Storage area and prep area	1. The OPSO issues the support directive as per SOPs 2. The field hospital logistics team verifies the order, locates and selects the deployable pack, and conducts final checks and packing		SOPs	Contents of the deployable pack Are there several iterations of deployable pack depending on the incident, or only one generic pack

5.2.1.7	The Health Unit navigates the deployment pack and deployment vehicle to the treatment site	Health Unit Logistics Team	OPSO Health Unit Health Unit Logistics Team S3 S41	OPSO Health Unit	The deployable pack needs to be delivered at best speed, in a usable condition, and faster than the CASEVAC	Field Hospital environs Routes and nodes to treatment area	Collocated with storage area and prep areas Ground or Air routes to treatment area	1. OPSO Field Hospital request ground or air clearance for the UAV or UGV. 2. The S3 issues clearance as per SOPs 3. The OPSO Health Unit directs the deployment of the UAV or UGV to the treatment site. This may be either remote operation or autonomous transport	UAV or UGV Remote or autonomous navigation and transit Deployable pack release		Clearances for UAV / UGV Redundancy in deployment? Enhanced Battle Casualty Treatment delivery vehicle - UAV or UGV, capability review Navigation equipment in operational units for Enhanced Battle Casualty Treatment delivery vehicle Low detection aspects to retain security of forward assets
5.2.1.8	Localised beacon activated to guide deployment vehicle to treatment area	ADF first responder	ADF first responder	ADF first responder	Depending on the delivery means, a method of guiding the supplies to the receipt point is required. This may be detailed grid reference, beacon, remote operation or some other signalling process	Treatment area and approaches		1. Receive indication of imminent arrival - comms or visual 2. Activate signalling device	Signalling device UAV / UGV distribution systems		Method to positively locate receipt location for delivery? Is there a way to wave off the UAV / UGV, delay delivery, or adjust delivery point once it is deployed? Should there be a primary and secondary option for this instruction to the UAV / UGV?
5.2.1.9	The ADF first responder receives the deployment pack and uses it to treat the casualty	ADF first responder	ADF first responder Health Unit Logistics OPSO Health Unit	OPSO Health Unit	The ADF first responder needs to receive the deployment pack in a safe manner that does not expose them to additional threat, and delivers appropriate supplies. It needs to be quickly and easily accessed to minimise time from treatment. The safe delivery needs to be receipted so that the Health Unit knows the supplies have arrived in a usable condition	The treatment area Field Hospital Comd post		1. The deployable pack arrives at the first responder location 2. The first responder detaches the deployable pack and accesses the supplies. This may include a comms device to enhance connectivity to an NO / MO. 3. The first responder then activates a response to the Health Unit acknowledging receipt 4. The first responder returns to the casualty and continues to treat 5. Any redundant deployment packs in transit are turned around 6. The deployment vehicle leaves the treatment area and returns to the Field Hospital for re-use			Does the UAV/UGV lad or drop? Response mechanism to acknowledge receipt Messaging to control movement once deployed (and change delivery locations) Video link enhancement at this stage? Detachment mechanism to minimise time accessing supplies Possible packing order to reflect treatment process? Low detection delivery means into treatment area Do we use beacons to guide the UAV/UGV in or is there some other guidance system? What happens if the casualty is declared dead?
5.2.1.10	Deployment vehicle moves to recovery point	ADF first responder	UAV/UGV asset	CSS unit	Deployment vehicle returns to a recovery point. This may be forward of the CSS / Health Units to extend the reach of the system	Recovery point (may be outside of the CSS / Health unit environs to extend the delivery range)		1. Return route either pre-programmed or directed on release 2. UGV / UAV travels as per direction 3. UGV / UAV back loaded as appropriate			How to direct return Back loading protocols Health asset or general asset?

5.2.1.11	The evacuation means arrives and transports the casualty to the next appropriate care facility	Casualty ADF first responder	Casualty ADF first responder S3 S41	S4	The casualty is evacuated by any means IAW SOP	The treatment area Designated next level care facility		1. As per formation SOPs 2. Any undelivered deployment packs in transit are turned around			Messaging to control movement once deployed (and change delivery locations)
5.2.1.12	END										
5.3	**Deviation and Exceptions**										
None specified											

5.4	End State (Post Conditions)										
	Why	**Who**			**What**	**Where**		**How**			**Investigate**
	Motivations	User	Actor	Owner	Needs / Aspirations	Location	Space Attributes	Facilitation	Technologies	Services	need to check on...
5.4.1	Enhancement of the ADF Battle Casualty Treatment system that improves the survival rates and injury recovery for personnel	Defence	Defence Technology and Industry Partners Partnering Defence Organisations	Defence	Available equipment and technology, method of employment, agreements, associated FIC all in place and operating	AO, AS and administrative areas	Storage and maintenance of deployment packs and vehicles SOPs to establish comms sites for NO/MO support operations	1. Develop operating concept and model effect of an Enhanced Battle Casualty Treatment system to determine likely value and employment 2. Select shortlist of technologies and conduct trials as appropriate. Assuming this is positive: 3. Establishment of technology development and acquisition program. This includes all aspects of FIC (fundamental inputs to capability) including doctrinal integration. 4. Identification of highest net benefit and prioritisation of effort. 5. Rollout and integration with current systems IAW prioritisation	UAS UGS Packaging Remote comms equip for ADF First Responder and NO/MO support	Test and trial services (DSTG, CASG, End User) Defence Legal Contract management including acquisitions (CASG) RAAMC	Operating concepts and doctrinal integration Value case a. Should Defence pursue enhanced battle casualty treatment? Liabilities and risks Defence Budget impacts

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19. ABSTRACT
Army Research and Development Request (ARDR) 16/0054 requires examination of the opportunities for employment and associated effects of autonomy and automation across Combat Service Support (CSS) functions. This report outlines the results of a scoping study, subject matter expert discussions and workshop, and use case development for automated and autonomous systems for CSS. The scoping study covers key concepts and trends, a technology scan, and identification of potential applications for logistic operations. The outcomes of the workshop with Army Headquarters personnel include prioritisation of the shortlisted technologies with the selection of the top four technologies for further research: predictive analytics, last-mile logistics unmanned aerial systems, portable networked health diagnostic technology, and semi-autonomous convoys. Further discussions identify key information requirements and delimiters for the selected technologies. The report goes on to present detailed use cases for two technologies of interest: semi-autonomous convoys and last-mile logistics unmanned aerial systems, including a use case for enhanced battle casualty care.