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Semi-Autonomous Combat Team Dismounted Infantry 2030 Concept

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EXECUTIVE SUMMARY

The Defence Science and Technology (DST) Land Capability Analysis (LCA) Future Technology Concept Exploration (FTCE) programme focusses on designing novel ways of operating to exploit and counter emerging technologies, and assessing the potential operational effectiveness of the conceptual and structural transformations. The results of these studies are provided to Army as recommendations for consideration of:

- research effort priorities
- shaping the future force
- thought and debate stimulation
- future warfighting challenges.

In conjunction with the Australian Army Dismounted Combat Program, LCA conducted a FTCE study in support of future soldier development. The study aimed to develop post 2030 exploratory concepts that would guide the long-term development of the soldier system and associated force structures and capabilities. The study was guided by the research question:

> How will combinations of new and emerging technology transform the battlefield engagement capability of Dismounted Infantry in Close Combat?

The study applied a systemic design approach that combined several analytical research methods with a creative, participatory co-design exercise to generate novel initial concepts for the post 2030 close combat force. This report provides a complete description of the Semi-Autonomous Combat Team (SACT) concept developed using the systemic design approach.

The SACT concept emphasises the integration a variety of unmanned systems (UxS), primarily aimed at substantially boosting capabilities at section level; linked, controlled and cued via a ‘combat cloud’.

Key tenets of the concept are:

- A shift to human-machine teaming relying on levels of supervised and delegated autonomy. This carries with it the need for appropriate levels of supervision and follow-on implications on human cognitive load and a range of outstanding legal, ethical, moral, and political questions.

- A significant change in approach to close combat where humans are no longer ‘first, last, and always’. The concept features humans acting extensively through other platforms to direct the close-fight, before engaging in it themselves where necessary.
- Several steps towards an abundance mindset facilitated by more risk-tolerant UxS platforms, compared to casualty averse and scarcity mindsets present today.
- An increased offensive operations ratio from 3:1 to 1:3 through the addition of UxS versus conventionally equipped forces. This is in tandem with an increase in survivability achieved through greater standoff and dispersion.
- The reality of an increasingly observed and sensor saturated battlefield means a necessary shift in tactics, techniques and procedures (TTPs). Operating above the general detection threshold is unavoidable due to the size and the number of platforms employed. Instead, the concept aims to stay below the ‘targeting solution’ threshold through inducing and sustaining ambiguity.

In terms of structure, a SACT combat team (CT) remains largely comparable to a present-day dismounted combat team. The syndicate considered a ratio of one human supervisor to approximately three platforms or systems serves as an appropriate yardstick given current expectations for autonomous capability.[1] Each fire-team holds approximately three dedicated (unmanned ground vehicle) UGV platforms and its own intelligence, surveillance and reconnaissance (ISR) cluster capable of undertaking three consecutive tasks (i.e. general local awareness, a specific investigation, and overwatch over key terrain). This structure then scales upwards throughout the CT with a 1:3 ratio as guide.

Participant subject matter experts assessed that SACT provided a substantial capability and survivability boost when compared against an equivalent conventional formation. Increased awareness, lethality, standoff, dispersion, responsiveness of organic fires, and coordination enabled by combat cloud dramatically increased expected performance – particularly against the challenges posed in highly complex terrain. The shift to an expected 1:3 offensive operations ratio mentioned above indicates the scale of the improvement.

These benefits, however, do not come without their share of risks and issues. First, the cost, sustainment, and lift factors of the SACT concept are considerable. The attritable and semi-attritable components only compound this issue. Second, the functional levels of autonomy core to the concept do not presently exist. While substantial progress is widely anticipated, there are no guarantees. Third, the prevalence of autonomous and

[1] Participants assumed a ‘teammate’ level of functionality capable of effective operation with low levels of supervision is achievable within the timeframe addressed by the study.

networked assets that are increasingly dependent on combat cloud for their functionality carries with it considerable risks from cyber and electronic attack. High-powered radio frequency (HPRF) attacks, similarly, pose a major threat. Finally, the increased number and sophistication of platforms combined with the communications requirements for SACT to function effectively will significantly increase signature. TTP and management measures can alleviate this somewhat, but only partially.

Nevertheless, the SACT concept offers an indicative guide to future possibilities. Pointedly, participants noted that without comparable increases in capability—whether in the form of SACT, or by another road—a conventional CT would find itself hard pressed against even ad hoc equipped adversaries repurposing COTS equipment.

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CONTENTS

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GLOSSARY

AFSS	Autonomous fire support section
AESA	Active electronically scanned array
AGL	Automatic grenade launcher
AI/ML	Artificial intelligence/machine learning
Bde	Brigade
BMS	Battle management system
C2	Command and Control
CIMIC	Civil-military cooperation
CIWS	Close-in Weapon System
COP	Combat outpost
CRAM	Counter Rocket and Missile
CT	Combat team
DEW	Directed energy weapons
DST	Defence Science and Technology Group
EMCON	Emission control
EMS	Electro-magnetic spectrum
EW	Electronic warfare
FOE	Future operating environment
FTCE	Future technology concept exploration
HEL	High energy laser
HMG	Heavy machine gun
HPRF	High-powered radio frequency
HQ	Headquarters
HUD	Head-up display
IADS	Integrated air defence system
ISR	Intelligence, surveillance & reconnaissance
JTARV	Joint tactical aerial resupply vehicle

LCA	Land Capability Analysis
LIDAR	Light Detection and Ranging
LOAC	Laws of armed conflict
MMG	Medium machine Gun
PGM	Precision guided missile
PL	Platoon
PNT	Position Navigation and Timing
RF	Radio frequency
RWS	Remote weapon station
SACT	Semi-autonomous combat team
SCSP	Soldier combat system program
SNCO	Senior non-commissioned officer
TTP	Tactics, Techniques and Procedures
UAV	Unmanned air vehicle
UGS	Unattended ground sensors
UGV	Unmanned ground vehicle
UxS	Generic label describing all types of unmanned systems (Unmanned <class> System)

1. INTRODUCTION

The Land Capability Analysis (LCA) Future Technology Concept Exploration (FTCE) programme explores the technologies, capabilities, concepts, and force structures future Army Combat Teams require to deliver tactical overmatch and dominance in all foreseeable engagements under all conditions and future operational environments (FOE). The programme focusses on designing novel ways of operating (concept exploration) to exploit and counter emerging technologies, and assessing the potential operational effectiveness (the performance) of the conceptual and structural transformations. The results of these studies provide recommendations for Army consideration in order to guide research priorities, shape the future force, stimulate thought and debate, and address future warfighting challenges.

Following discussions with the Army Dismounted Combat Program (DCP) it was agreed that DST LCA would conduct a FTCE study in support of future soldier development. The study would develop post 2030 exploratory concepts that would guide the long-term development of the soldier system and associated capabilities. The study is of significance, as Army needs to prepare for a future where 'advances in sensing, precision attack, and decision-making will fundamentally alter the character of future conflict engagement'.[2]

1.1. Advanced Engagement Battlespace

The FTCE study was aimed at exploring future advanced engagement concepts guided by the research question:

- How will combinations of new and emerging technology transform the battlefield engagement capability of Dismounted Infantry in Close Combat?

Where:

- technology are those capabilities assessed to be viable in 2030 timeframe
- battlefield engagement is framed by the lower tactical functions of find, fix, strike and exploit[3]
- infantry is light infantry[4] including unmanned enablers at the Combat Team level.

[2] https://smallwarsjournal.com/jrnl/art/advanced-engagement-battlespace-tactical-operational-and-strategic-implications-future

[3] Land Operations, Land Warfare Development Centre, UK Army Doctrine Publication AC 71940, 2017

[4] Future studies will explore the mounted infantry combat domain

The study assumed that close combat is enduring and involves a 'collision between two living forces', i.e. close combat still requires human interaction and that robot wars have not come into existence.

1.2. Methodology

The study adopted a systemic design[5,6] approach to answer the research question. This approach combined several analytical research methods with a creative, participatory co-design exercise in order to generate novel initial concepts for the post 2030 close combat force.

The systemic design method guides the analysts through:

- foresight scenarios
- concept/inspiration cards
- historical analogue
- divergent brainstorming
- innovation ambition matrix
- idealized design
- wind tunnelling
- concept sketch
- from-to shifts
- riskiest assumption identification.

The options generated in this study are intended to be novel, plausible and transformational. They require further feedback, analysis and refinement before they should be used to inform conceptual aiming points for future dismounted Combat Teams.

A four-day systemic design workshop was held at DST Edinburgh (September 2019) with Army participants (SNCO and Officers) who had strong infantry knowledge base, and DST technology experts and operations analysis staff. Over the four days the participants were guided through the systemic design process which enabled them to be immersed in future scenarios and post 2030 technological space[7], and gain an understanding of divergent

[5] Ryan, A. A Framework for Systemic Design.FORMakademisk2014,7, 1–14

[6] The approach was previously used to study Australian Army in 2050.
Joint Studies Paper Series No. 3, Design Thinking: Applications for the Australian Defence Force: 'Systemic Design of a Force for the Australian Army in 2050' by Brandon Pincombe *et al*

[7] A total of 108 emerging technologies and concepts were presented

conceptual evolution in the 1920/30s and its ramifications.[8] The participants were then separated in to two syndicates that mixed Army and DST participants to design and develop the future concepts. Two detailed concepts were generated during the workshop. The workshop concluded with an assessment of concept effectiveness against future scenarios and a risk identification assessment.

This report details the Semi-Autonomous Combat Team (SACT) concept, its sub-concepts and the supporting force structures generated during the systemic design workshop. The report concludes with a performance assessment of the concept.

As noted above, future scenarios are used to enable an understanding of the contexts and challenges any future-orientated design must satisfy and secondly provide test environments to evaluate the performance of the designs. The scenarios and associated vignettes used in this study are summarised in Table 1. A set of vignettes derived from past experiments and historical battles have been classified by the four scenario themes representing different tactical situations and terrain; the threat forces being encountered, and the type of mission to be conducted – offence or defence overlay.

Table 1 Scenario Space

	Scenario Themes			
Threat	**Tropical Battlefield**	**Urban Battlefield**	**Subterranean Battlefield**	**Airmobile Operations/ Isolated Position**
State-Sponsored Hybrid	1.B Long Tan	2.A Marawi	3.A Cu Chi	4.B Secure Airfield 4.C COP Keating
State Force	1.A Borneo	-	3.B Toronto	4.A Coy Block

Offence   Defence

[8] Reflection on the divergent concept development by France and Germany in response to post-WW1 analysis during the inter-war period.

2. SEMI-AUTONOMOUS COMBAT TEAM CONCEPT

2.1. Concept Overview

Following the contextualisation and technology immersion phase of the design process, the syndicate reflected on the challenge of designing novel and transformative concepts against engagement capability on the future battlefield. Through processes of discussion and reflection, the syndicate seized on several key emerging technological developments to significantly boost the lethality, situational awareness, and indirect engagement capability of the CT, while also improving its survivability through increased standoff and dispersion. Four key elements feature in the design:

- A persistent, self-organising, sensing field comprised of a mix of largely autonomous UxS collaboratively achieves distributed multi-spectral sensor fusion in the area surrounding each section.
- Armed small/medium UGVs with modular mounts capable of fitting remote weapon station (RWS) weapon systems. Smart fire control systems substantially extend their accurate and effective range, enabling them to bridge a larger standoff gap facilitated by improved ISR.
- Small attritable 'breach-bots' capable of performing high-risk ISR inside structures and complex terrain, performing smart area denial, and assaulting prepared defences to achieve initial breach for follow-on strike by armed UGVs and human elements.
- A 'combat cloud' underpinning the above that is capable of securely and resiliently linking this diverse range of platforms together within each section and facilitating the necessary C2 and UxS management. This locus of control and supervision is contained within each section to aid responsiveness.[9]

The key trend underlying the SACT concept is the transition from human-centric close combat to human-machine teaming close combat operations. Integrating UxS extensively throughout the CT enables higher risk tolerances and the effects of greater mass at the section level, without requiring additional human mass or the risks and costs that typically implies. Organic UxS elements integrated into infantry sections grants sections increased independence, mass, resilience, and capability. Greater organic capabilities also reduce the reliance on continuous communications and other echelons for support, increasing operational flexibility and tempo.

[9] Each section level element hosts its own independent combat cloud as communications with higher or surrounding echelons are presumed intermittent, high-latency, and not sufficiently reliable for meaningful coordination or supervision of UxS. The strong probability of a heavily contested electromagnetic spectrum (EMS) further underscores the importance of local control in the land context. Put simply, communications within the section are essential, while communications with other echelons are beneficial but optional.

A shift towards human-machine teams prompts three key considerations:

- What is the appropriate level of supervision required to support semi-autonomous systems in the field while conducting close combat, and while observing our Laws of Armed Conflict (LOAC) obligations? Discussions within the syndicate and consultation with available SMEs led the syndicate to view approximately three distinct platforms/self-organising clusters of UxS per individual as a useful rule of thumb. The structure and roles of SACT sections follow from this understanding.10
- What is the impact of attritable and semi-attritable platforms within a CT? Attritable UxS platforms enable shifting risk burdens away from human operators. Instead of humans first, last, and always - UxS can stand-in on riskier tasks and undertake the 4 D's (dangerous, difficult, dull, and dirty).
- What are the implications of a shift from a scarcity to abundance? The SACT paradigm features sections sensing, moving, and fighting through their resilient and/or attritable UxS platforms first, while human members retain greater standoff and dispersion. To what extent should these platforms be attritable, what benefits and costs does that create at the tactical level, and what are the ramifications at Bde level of that shift?

Balancing these considerations drove the design process. The syndicate explored them by designing from the bottom-up, as the greatest impact of the briefed technologies was understood to be at the immediate tactical level. Beginning with the integration and exploitation of UxS systems at the section level, the core concept was then scaled upwards to build a full CT and explore Bde level requirements and implications. The description contained here follows the same pattern, beginning with the key sub-components at section level, then exploring core and enabling technologies and concepts, before considering overall force structure and wider implications.

Syndicate participants highlighted the following key benefits of the SACT concept:

- Increased tempo supported by the ISR field.
- Enabled alternative tactical paradigms in complex terrain affording increased awareness, lethality, standoff, and survivability.
- Greater mass and independence at the section level achieved through an increase in organic capabilities within each section.
- A corresponding reduced reliance on other echelons.

[10] This is a rough guide based on participant's conservative estimates of achievable levels of autonomy and desirable levels of supervision. These are, of course, likely to change dramatically at matters progress. SACT aims to present a baseline structure that is suitable for scaling upwards if appropriate and levels of autonomy exceed the participants deliberately conservative expectations.

- Substantially improved engagement ratio – from 3:1 to 1:3 (i.e. can potentially engage and defeat conventionally equipped Red forces up to 3 times larger in the context of the Jungle scenario).
- Reduced personnel requirements by ~20% for the overall CT.

However, there benefits attract a range of costs and complex considerations, including:

- Increased logistics burden, cost, and training requirements.
- Vulnerabilities stemming from increased technological reliance in the close fight.
- A wide range of as-yet unresolved moral, ethical, legal, and political considerations surround the use of semi-autonomous platforms in warfare.

The key aspects of SACT can be loosely broken into three sub-components: the sensing field, UxS direct engagement platforms, and indirect engagement. The following sections detail these components, the core and enabling technological dimensions of the concept, and present an indicative force structure for the semi-autonomous combat team. However, a brief note is necessary before continuing into a deeper exploration of sub-components and sub-concepts. The descriptions and details that follow are only illustrative and intended to indicate promising lines of future research and development, not present a comprehensive blueprint.

2.1.1. Visualisation of the concept

The following figures illustrate the broad battle formation and arrangement of a SACT section with indicative UxS platforms. As the concept and its immediate description to follow are centred on the section, further figures illustrating the full CT arrangement are provided later in the Force Structure section of the report.

Figure 1 illustrates the arrangement of platforms, forming layers of UxS preceding and trailing the human members of a SACT section. Note the extension of the sensing ISR field extending throughout the full formation. Figure 2 illustrates the mirrored arrangement of each section as two, three-man fireteams supported by and acting through multiple UxS systems. The wider CT structure composes of UxS equipped sections remains relatively standard, with three sections to each platoon and three platoons to the CT. A noteworthy exception is the addition of an Autonomous Fire Support Section (AFSS) attached to each PL HQ. This provides semi-autonomous provision of heavier firepower, including larger loitering munitions, at the PL level based on the same modular UGV platforms employed within each section. This further reduces the reliance on higher echelons for support.

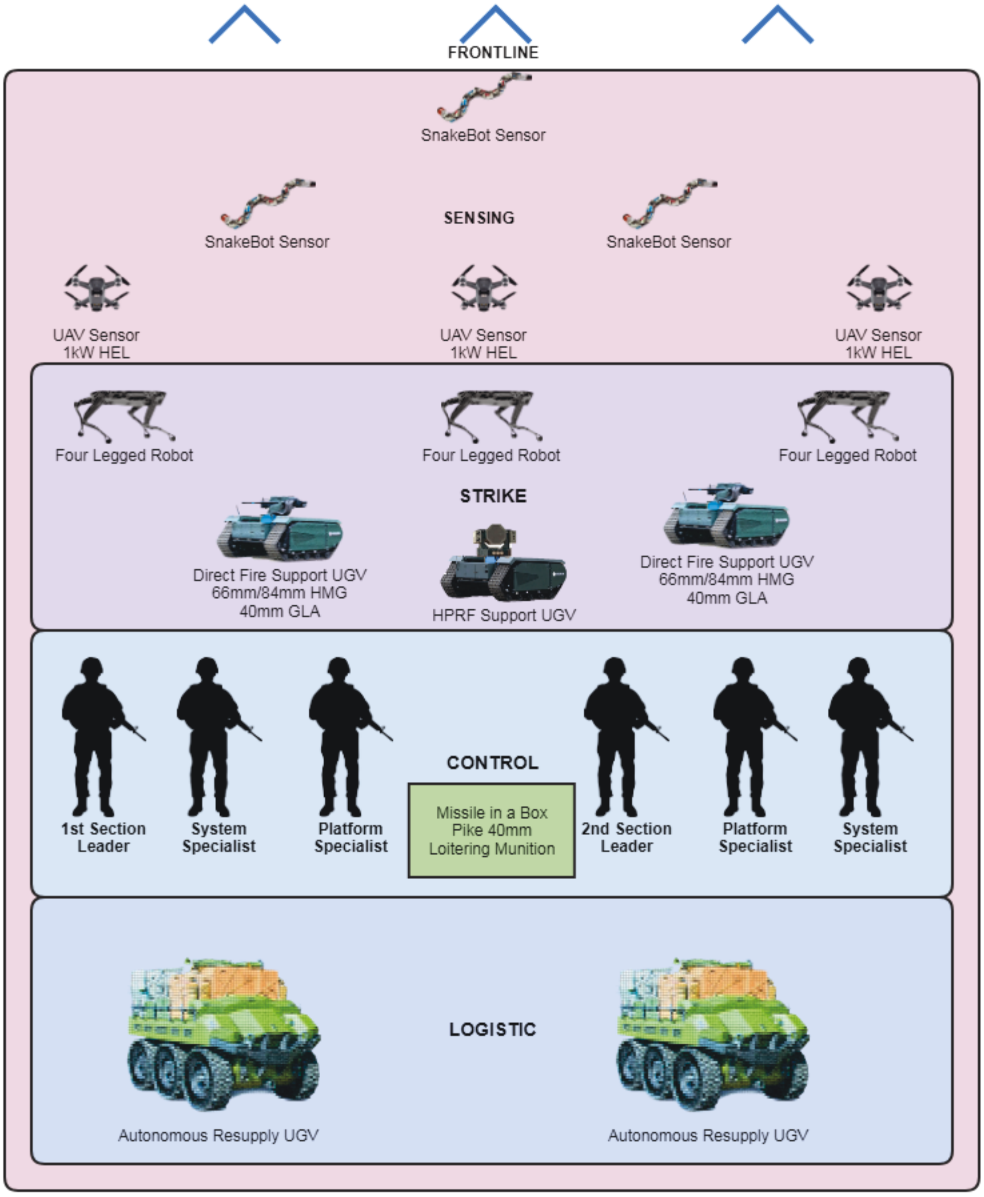

Figure 1. SACT battle formation at section level, indicating layers of UxS employment extending outwards from the human core of the section

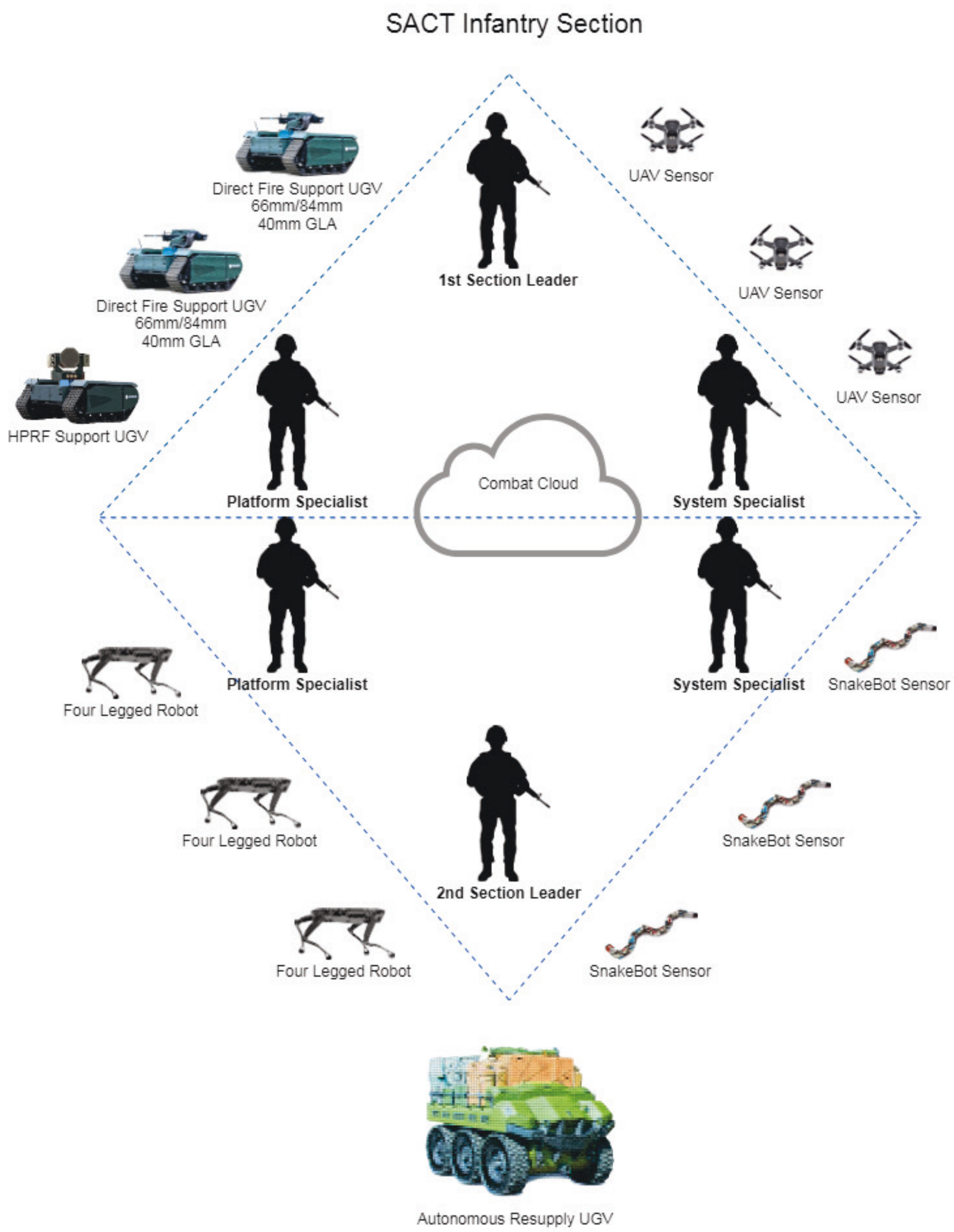

Figure 2. SACT section organisation with indicative UxS platforms

2.2. Sub-components

As noted above, at the section level SACT is comprised of three main sub-components, a sensing field, semi-autonomous direct engagement, and organic indirect fires.

2.2.1. Sensing field

The Sensing Field is a core element of the SACT concept facilitating many of its strengths. Advances in sensor technology that includes, hyper/multi-spectral, thermal, acoustic, electronic, chemical, seismic, laser, and radar including small radar arrays with foliage penetrating capabilities, indicates that future close combat environments will be on a sensor-saturated battlefield.

The Sensing Field aims to leverage these advances to facilitate complex and comprehensive sensing organically at section level and immediately responsive to a rapidly shifting tactical environment. The intent is achieving persistent and detailed ISR coverage surrounding each section through a mix of self-organising/managing, collaborative, UxS platforms. Combined with sensor and data fusion via combat cloud, the Sensing Field affords a high degree of awareness to the section on its surroundings and objectives. This was understood to increase tempo, reduce risk, and support engagement at extended standoff ranges.

Platforms

The participants envisioned the Sensing Field as achieved by a variety of platforms with varying capabilities. These can be divided into three broad categories:

- UAVs - Comparable to present day options, including various sizes of quadcopters, small fixed wing aircraft, and solider borne mini-UAVs similar to Black Hornet.[11] Perching capabilities were also highly rated to increase the endurance of small UAV platforms. The addition of logistics sleds providing additional carriage increases the sustainment capability for these platforms, and enables persistent operation via rotation. Similarly, additional carriage and sustainment capacity provided by logistics sleds (detailed later) enable the employment of larger UAV platforms at the section level.
- Micro UAVs and micro-electromechanical system (MEMS) platforms - Smaller flying platforms (mm to <5cm scale), such as RoboBee, and other similarly sized options provide persistence in a given area while less observable and without requiring the dedication of larger and less expendable assets.[12] Their limited mobility across a large battlespace is addressed by employing larger UAVs as motherships to distribute them to achieve low profile, static ISR in key areas. MEMS platforms, such as 'smart

[11] The nature of available platforms is likely to change dramatically within the 2030+ timeframe. The syndicate opted to work from indicative capabilities rather than anchor the design around specific platforms.
[12] These are small and effectively disposable platforms. Deployed *en masse* they are capable of limited manoeuvre and distributed sensing over an area. See: https://wyss.harvard.edu/technology/robobees-autonomous-flying-microrobots/

dust',[13] offer a more limited range of capabilities with less mobility. However, their low profile, ability to drift with air currents, and more thoroughly permeate urban environments through air ducts, for example, gives great utility.

- Small UGVs - Provide key capabilities to the Sensing Field. There are a range of extant models that show promise. In particular, 'Snakebots' feature heavily in the SACT concept.[14] Participants envisioned these as modular, extensible chains composed of many independent sections. These are capable manoeuvre through highly complex and varied terrain (i.e. urban, jungle, riverine, etc.) while maintaining a relatively low profile. Segments detach and remain in place to perform various functions, such as unattended ground sensors (UGS) for low-profile static ISR, as claymore-like anti-personnel (AP) mines, or as communications relays facilitating or extending battlefield networks through complex terrain. Once tasks are completed, segments can be recovered and reintegrated, enabling repeated use over the course of a mission. Their relatively slow ground movement speed can be improved by using UAVs as shuttles to move snakebots around the battlefield.

Participants also considered snakebots especially useful for establishing defensive perimeters in complex terrain with minimal ground sign or other indications. The concept as a whole features many snakebots perform roaming ISR and emplacing/recovering segments surrounding the section as it manoeuvres, holds, or assaults.

Capabilities

ISR platforms host a range of capabilities, many of which are distributed among the whole system. Broad hyper/multi-spectral capabilities are achieved through fusion between platforms, rather than attempting to mount overly complex, bulky, and expensive sensors to every individual platform. Much as with the wider SACT concept, efficacy is achieved through a mass of cheaper and more risk-tolerant UxS rather than few 'exquisite' platforms with correspondingly low risk tolerances.

In terms of broad functionality, key features would include:

- Self-organisation and management capability. This includes navigation, mission-oriented ad hoc collaboration, and system management sufficient to enable relatively independent action without a reliance on direct C2. Particularly important is terrain awareness and masking behaviours to enhance UxS survivability in a contested battlespace.

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[13] Smart dust is one proposed application of MEMS where a large number of tiny (<1mm) platforms called 'motes' are spread in an environment to achieve distributed sensing.

[14] In addition to in-brief materials in a forthcoming report, see: https://www.houstonmechatronics.com/snakebot/

- On-board classification of sensor detections. This needn't be to the point of full identification. Isolating detections from noise on-board each platform eases transmission requirements compared to full-feeds that require complex processing or human assessment. Identification, complex analysis, and fusion can be performed centrally by the combat cloud suite.
- Dynamic mesh networking and relay capability between platforms to better facilitate redundant communications in complex terrain at lower power levels. This includes asynchronous burst/batch communications.
- Cyber & physical security measures sufficient to guard against data and network compromise via captured platforms.

Ultimately, capabilities combined across the entire ISR system should enable complex hyper/multi-spectral, multi-platform, asynchronous sensor fusion. Ideally, sufficient platforms are available to achieve persistent ISR coverage, with elements cycling in and out for recharging by the section's logistics assets.

Several high-end sensing capabilities were also discussed, such as integrated foliage penetrating radar integrated with other sophisticated sensing methods on a small-to-medium sized airborne platform. This would be highly advantageous, however the expected bulk, cost, and limited endurance resulting from the size and power requirements implies that assets similar to this would be employed selectively, rather than as a persistent component of the Sensing Field.

Finally, there is a role for lightly armed platforms within the ISR system capable of skirmishing and denying adversarial ISR. A previous Direct Energy Weapon (DEW) study conducted under the FTCE program included a standard quadcopter UAV fitted with a 1kW HEL for light counter-material and counter-air purposes. This was included in the in-brief material and considered highly beneficial by the participants in fighting the ISR battle and protecting the ISR screen without revealing more precious assets. The notion of armed ISR platforms and ISR skirmishing is an area deserving of further research.

Organisation

The Sensing Field aims to achieve persistent ISR coverage saturating the immediate and intermediate areas surrounding the section and larger CT. To achieve this, the Sensing Field concept focuses multiple individual ISR platforms arranged into self-organising clusters. These may form, reform, and scale dynamically as needed, depending on where the operator wishes to prioritise their ISR resources. Each cluster is tasked by human operators with area(s) or objective(s) that require ISR, and then self-organises its platforms to achieve that task. Operators can set appropriate parameters for the effort, such as proportion of resources, noise, risk, and observability levels. In this way, human operators supervising the overarching system only monitor and manage a handful of self-managed clusters, with the minutiae handled autonomously. System specialists will have the ability to engage the ISR system at deeper levels as part of their role in its management, while other section members will only need to process the eventual output. Overall, at each level the ISR system appears calm on the surface while a hive of activity continues beneath.

The ISR system then presents its findings as resolved output, annotated to display the nature and degree of coverage achieved with appropriate metadata on any detections.[15] This enables human operators a swift understanding of the battlespace and avoids overwhelming them with errant or excessive data while still allowing humans to intuit beyond the available data. Many of the concepts and procedures for this can be adapted from similar existing paradigms in other warfighting domains. Similarly, many forms of digital entertainment have made great strides in presenting complex and rapidly changing environmental information in informative and readable formats.

2.2.2. Semi-autonomous direct Engagement

Leveraging the information and standoff provided by the Sensing Field, armed UGV platforms provide the bulk of a SACT section's mass and direct engagement capability. Human-machine teamed close combat operations as envisioned in the SACT concept sees armed UGVs acting as the lead element, performing engagement, base of fire, overwatch, and clearance tasks ahead of their human operators.

[15] One example might be heat-map overlays indicating where ISR platforms have scanned, how long ago, and with what manner of sensors. The Android Team Awareness Kit (ATAK) software already supports similar mapping for line-of-sight calculation based on topographic data and observer location. See: https://youtu.be/tojMXYMVdyw?t=94
Metadata would include details such as the method(s) and platform(s), detection spectrum(s), degree of alignment between various detections and various platforms, and a derived confidence measure.

Platforms

Small-to-medium UGVs provide the main direct engagement capability for the SACT concept, with human soldiers equipped with SCS combat suite augmenting where appropriate.[16] Wheeled, tracked, and/or legged UGVs were considered.[17] Each has advantages depending on the demands of the scenario and technological advances in the interim.[18] These would be resilient against small arms, and potentially fitted with extendable shields capable of providing moving cover to human operators when approaching objectives under fire.[19] Low-signature modes of operation would also be required as a component of signature management.

Armament

Modular RWS-style armaments provide key engagement capability. Various types—many being conventional—were discussed, including MMG/HMG/miniguns, AGLs, and more exotic options such as directed energy weapon systems.[20] Modularity enables mission specific selection and alteration, as well as service/replacement of weapon systems independently of UGV platforms. 'Smart' fire control systems enable high degrees of precision at extended ranges for both UGVs and human SACT members, enabling and enhancing the ability to engage at extended ranges with cueing and support from the Sensing Field.

Highly accurate targeting provided by 'smart' fire control, combined with multi-spectral sensor fusion, also potentially enables the section to provide a form of close-range IADS suitable to contest enemy UAVs and other interstitial airborne threats that fall below the conventional air domain.[21] HEL and HPRF capabilities also provide key advantages in this regard. One example discussed involved a 50kW HEL system on a medium UGV sized platform. This significantly boosts the light counter-air capability available to each section with minimal additional munitions or sustainment requirements. HPRF generators and/or explosively formed methods of HPRF generation are also highly useful against weight-

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[16] SCS solider suite was briefed during the introductory process. Participants broadly regarded the SCS solider suite as baseline capability for the SACT concept.

[17] Contemporary examples include Milrem's 'THeMIS' UGV, Rheinmetall's 'Mission Master', Boston Dynamics' 'Wildcat', or QinetiQ's 'MAARS' platform.

[18] Legged models such as those from Boston Dynamics show considerable promise, as does the related field of soft-robotics. These promise considerable advantages in mobility through complex terrain, approaching or even exceeding that of human operators.

[19] 'The Swift Shield' offers a contemporary example of a lightweight folding shield with modest protective capability. See: https://newatlas.com/military/origami-inspired-swift-shield/

[20] The syndicate also discussed the use of small human operable weapon systems in the interest of redundancy should a UGV become disabled.

[21] The lessons of Mosul and the fight against Daesh highlight this interstitial domain as increasingly important for land operations within complex terrain. For a discussion of the topic, see: https://warontherocks.com/2018/05/air-superiority-under-2000-feet-lessons-from-waging-drone-warfare-against-isil/

constrained UxS, general electronics, and communications equipment. Though HPRF is substantially more observable compared to HEL, the syndicate rated disruptive/destructive capability of HPRF highly enough to nominally include one HPRF equipped UGV per fireteam.

Behaviours

Independent of the specifics of the weapon system, the RWS platforms were assumed capable of semi-autonomous manoeuvre under human supervision. Platforms capability and mobility follow from the assumption that advances in autonomy will enable a ‘teammate’ level capability within the 2030+ timeframe. Individual platforms will be capable of acting independently and collaboratively, though still under human guidance. That is, capable of navigating complex terrain without close supervision, avoiding high-risk positions, selecting appropriate firing locations, and adopting basic behaviours to manage signature and observability.

For engagement, advances in sensing and additional data available from the Sensing Field were understood to provide reasonably reliable identification and discrimination of targets at extended ranges. Under close human supervision, semi-autonomous engagement in designated areas with positive identification requirements should be feasible. Conceptual models comparable to CIWS systems may be appropriate, where humans start-the-loop and oversee engagement of identified targets, within specific bounds and constraints.

Taken together, UGV platforms should be capable of undertaking the majority of tasks with little more than overarching guidance and approval from human operators, only occasionally requiring refinement of courses of action or error recovery aid. Human operators will retain the ability to fine-tune, offer specific directions, or remote control platforms if needed in order to best realise command intent.

2.2.3. Organic indirect engagement

A key differentiator of the SACT concept is the level of indirect engagement capability organic to the section. This increase in capabilities boosts engagement capability, lethality, extends achievable standoff ranges, and significantly expands each section’s ability to act independently. This is highly beneficial in terms of operational tempo and under contested EMS conditions that complicate any reliance on other echelons. Indirect engagement within the section takes three forms: PGMs, loitering munitions, and ‘breachbots’.

Precision Guided Munitions (PGM)

Large numbers of small PGMs are included within each SACT section.[22] Due to their relatively small size, these may be carried and operated by human operators in a similar manner to existing 40mm grenades, with an ample reserve capacity stored on UGV logistics platforms. Alternatively or simultaneously, a 'hedgehog' missiles-in-a-box UGV launch platform was discussed to increase the potential volley size, streamline the launch process, and increase responsiveness. Rather than requiring cueing and firing as sequential actions, a hedgehog system can launch immediately upon cueing via combat cloud. This may take the form of an arsenal-UGV shadowing the section at a suitable distance, or smaller hedgehog capabilities distributed amongst the other UGVs.

Whatever the method, the presence of small PGMs enables engagement of key targets with precision at standoff ranges on-demand within the section. This increases the section's lethality and does so without a reliance on other echelons, unmasking of long-range fires, or the presence/commitment of high-end air assets.

Loitering Munitions

Loitering munitions also provide a key indirect engagement capability to a SACT CT. Loitering munitions perform offer the ability to achieve remote cut-off without the extension of SACT elements, interdicting enemy movements, and more easily targeting key targets of opportunity such as vehicles and command posts with limited exposure.

Some smaller variants would be held within each section, such as DefendTex's 'Drone-40.' This contemporary system is easily man-portable and launched from existing 40mm launchers. Much like the Pike missile, it is easily carried *en masse* with the aid of UGV carriage. Larger variants, such as the Hero-120, are held by the AFSS under control of Platoon HQ. These can be launched largely autonomously from suitably equipped UGVs.

The presence of loitering munitions, both within the section and larger variants provided the AFSS, was highly prized by the syndicate participants. With appropriate payloads, these offer tremendous capabilities to a SACT CT in a reliable and responsive form that enables greater lethality and tempo.

[22] Present-day examples include Raytheon's 40mm 'Pike' missile. It was assumed that continuing advances in optics, processing, and production processes will permit modestly capable seeker-heads at low cost in the future, providing a further boost to their precision engagement capability.

Breachbots

Breachbots provide the chief attritable component of the SACT concept. These were envisioned primarily as ground-based.[23] Deployed on-demand and *en masse* from UGV carriers, Breachbots would be relatively small, cheap, and with relatively limited range.[24] Breachbots are capable of modest *ad hoc* swarming capability, enabling collaborative engagement as waves that locate and attack designated targets. Targets may be pre-sighted, cued by the ISR field, or potentially identified in battle through on-board sensors if appropriate. Human operators will define clear boundaries and limits on movement, engagement, and target profiles to de-conflict and ensure LOAC compliance.

Breachbots primary function is to reduce defended positions and achieve an initial breach for exploitation by following UGV and human elements. Other potential roles might include high-risk ISR such as inside structures or particularly troublesome complex terrain that precludes access by other ISR assets. Additionally, similar to the functionality of Snakebots, Breachbots could act as a form of 'smart' area denial capable of controlling key terrain and approaches to shape or achieve cut-off in complex terrain; i.e. jungle, urban, and subterranean where overhead obstacles hinder loitering munitions. This would achieve tactical effects comparable to a minefield while also capable of self-deployment, adjustments, self-recovery/disarmament, and the discrimination of legitimate targets.

Ideally, Breachbots are modestly capable (given their attritable nature), multi-role, platforms suitable for saturating complex terrain with sensors and 'smart' weapon systems under close human supervision.

2.3. Core and Enabling Technologies

A range of core technologies and sub-concepts inform the concept and the employment of sub-components described above.

2.3.1. Combat cloud

During the introductory stages of the workshop, representatives from SCS briefed the participants on current efforts and lines of development, including the 'Combat Cloud' data

[23] Aerial options were discussed; however, PGMs and loitering munitions already fill much of this role within the section. The additional logistical and sustainment burden is difficult to justify for another largely similar capability.

[24] Required range should be sufficient to commence an assault from standoff distances– i.e. 2-3 km. Coordination and traversal delays would require potentially several hours of passive endurance as well. A potential present-day indicative analogue used during discussion is the Recon Robotics 'Throwbot 2' platform. These are fitted with a small (non-lethal) explosive charge and are capable of navigating various terrain and obstacles. Alternatives with projectile weapons, such as the 'DOGO Tactical Combat Robot,' were also discussed. The advent of smaller, faster, cheaper and largely 3D printable options is highly likely within the 2030+ timeframe.

collaboration network. This is planned as a tactical-team level digital architecture facilitating seamless connections between many platforms and agents (human, robotic, and data, autonomous, and otherwise) into a coherent and manageable whole via a shared application layer. SACT uses this expected functionality to support communication, data exchange, multi-platform sensor fusion, and collaborative engagement.

An important detail is that the combat cloud platform is held and operated at the section level. This ensures availability and responsiveness within each section, even under contested EMS conditions. BMS and other similar systems provide linkages to lateral and higher echelons, but critically as an optional input and output to/from each compartmentalised section's combat cloud not a requirement. Structuring communications in this manner affords greater resilience while retaining the benefits of wider connectivity where feasible. Finally, it is essential that individual components within the section can fail gracefully should combat cloud or its supporting networks struggle. This may take the form of more limited functionality modes, or 'failsafe' standing orders in the event of communications loss. Figure 3 and Figure 4 illustrate the intended role, architecture and structure of combat cloud.

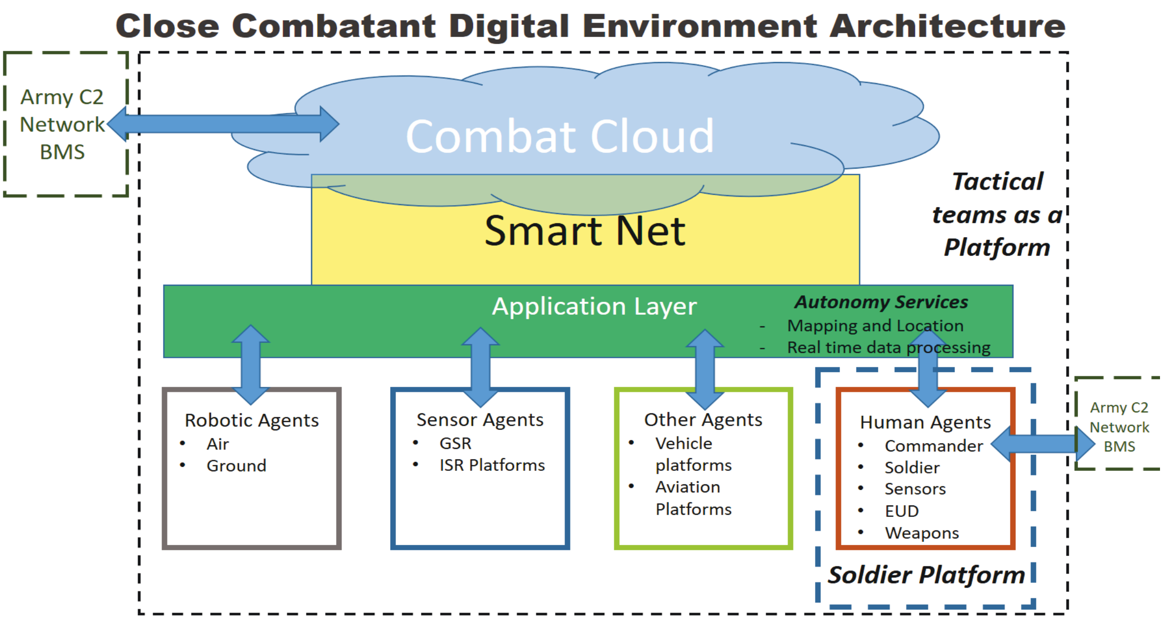

Figure 3. Indicative SCS Combat Cloud Architecture

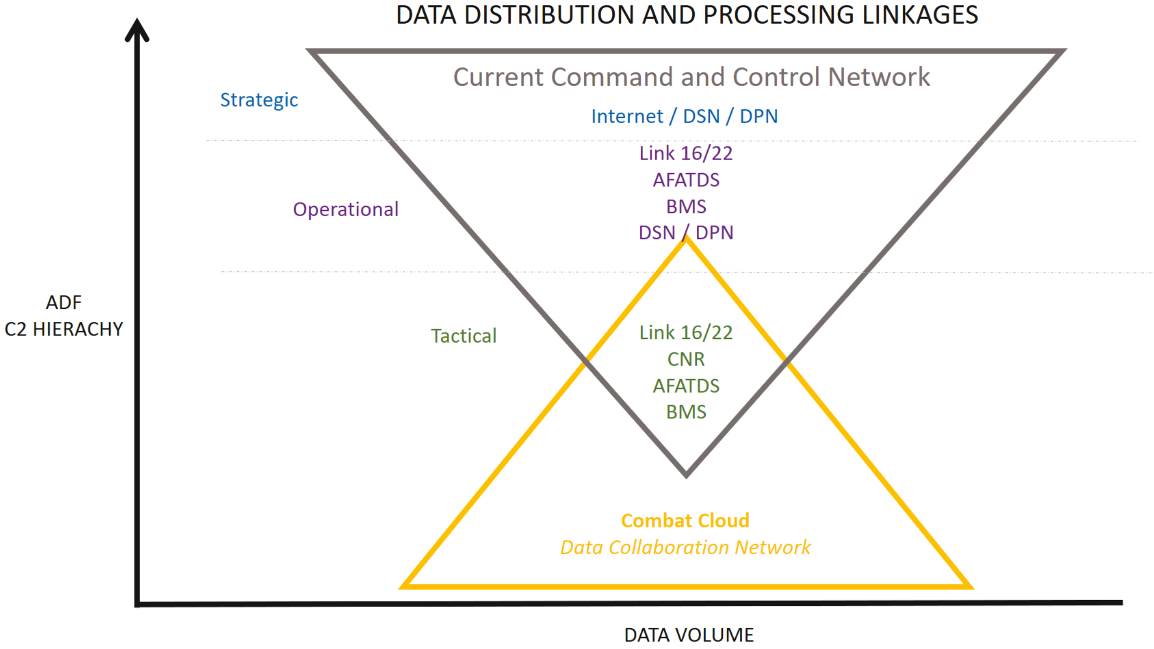

Figure 4. SCS Combat Cloud Integration

Also briefed by SCS and LCA during the introductory phases of the workshop were a variety of human interface devices directly integrated with combat cloud. Examples include heads-up-displays and other interface systems conveying the relevant information to individual soldiers provided by combat cloud.[25] SCS' brief included an additional discussion of automatic filtering of data flows to manage high volumes of generated data, given the increase in sensors and platforms feeding into the combat cloud. These discussions informed the syndicate's position on the appropriate levels of information, supervision, and cognitive load.

The syndicate understood that combat cloud includes reasonably assured mesh and/or asynchronous low-latency C2 within the section, high-latency communications with higher echelons, assured PNT, and collaborative engagement support with target handoff capability. Also considered was some measure of AI decision support that may be available within the timeframe. However, due to the uncertainties this was largely left for later consideration. Overall, combat cloud provides the key backbone of command, communications, coordination, and data fusion functions necessary to deploy and leverage UxS in the manner required by the SACT.

Obviously, there are multiple technical challenges yet to overcome. Examples discussed by the syndicate include the importance of user interface (UX) design, intuitive interfaces, and

[25] See the ATAK android application for an example of a present-day tactical C2 system similar to the combat cloud concept.

the ever-present need for robust cyber security for the ever-expanding number of computerised systems and platforms. Furthermore, the strong probability of electronic warfare and jamming presents a major complication for the communications systems upon which the concept depends. While it was assumed that reasonably reliable and punctual communications within the section are achievable, links to higher and lateral echelons are far less certain and more prone to interruption. This was a major element directing the syndicate to focus on bottom-up design, where the minimum required communications could be more safely assumed.

2.3.2. SCS future soldier suite

Included in the in-brief was an overview of SCS' future soldier suite. This includes elements such as exoskeletons, advanced armours with integrated multi-spectral camouflage, medical management and response systems, smart rifles with advanced targeting and ballistics calculation, on-board sensors with sensor fusion, power management and harvesting capabilities, AI decision support, and a fully integrated HUD system. The syndicate treated the full suite as baseline for dismounted combatants in the 2030+ timeframe. Many of its sub-components aid and facilitate the wider SACT concept, particularly the HUD and other human interface components critical to monitoring and managing UxS platforms. Figure 5 is indicative of some of these efforts.

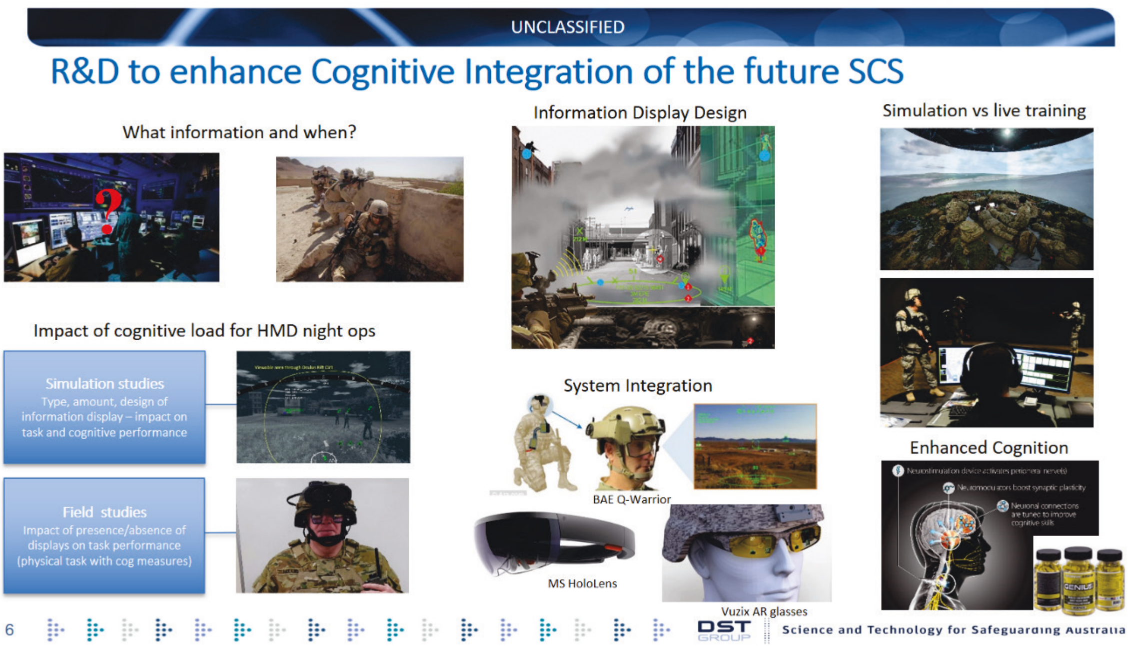

Figure 5. SCS plans for cognitive Integration within Soldier Combat System

In general, the full suite is assumed to improve human endurance, carriage, survivability, and C2, collectively providing the foundation required for SACT. Due to the increased standoff for human operators, the information management and interface components are the most directly relevant aspects in terms of core and enabling technologies.

2.3.3. Sensors and sensor fusion

Sensor fusion is the process of merging data from multiple sensors, improving robustness, increasing fault-tolerance, and reducing the degree of uncertainty. This process promises significant improvements in the overall availability of digital environmental data. In particular, hyper/multi-spectral sensor fusion facilitates comparing and assess sensor detections across many methods and spectra of detection increases the scope for possible detections while also increasing the information available to differentiate false-positives and provide identification/classification of confirmed detections. Advances in other warfighting domains demonstrate some of the impressive results achievable.[26]

As discussed in the Sensing Field section above, the SACT concept aims to leverage these advances via direct on-board classification of possible detections that are transmitted with necessary meta-data via the combat cloud platform for fusion into a nuanced environmental picture. The technical challenges to accomplish these between multiple platforms and sensors asynchronously are considerable, but believed generally feasible with modest efficacy within the timeframe. Combined with expected advances in sensor capability, SWaP characteristics, and AI/ML supporting data fusion, the future battlefield will be sensor-saturated and increasingly observed. Perhaps not to the point of transparency, but certainly less opaque than the present.

2.3.4. Autonomy

Achievable levels of autonomy within the 2030+ timeframe play a central significant role in SACT. Rudimentary levels of narrowly tasked autonomy are achievable today with substantial advances anticipated by many. However, even if those advances eventuate, the syndicate expected that some level of supervision in combat would still be highly advisable, if not outright necessary. In addition to the legal, ethical, moral, and political drivers, human supervision aids tactical efficacy by:

- Coordinating complex layered effects.
- De-conflicting the multiple UxS elements employed in tandem.
- Averting or mitigating errors.
- Providing on-site human-on-the-loop authorisation and supervision with reduced communications dependency.

[26] Fifth Generation aircraft such as the F-35, for example, achieve highly complex sensor fusion on-board granting them substantial battlespace awareness. However, the land context—particularly complex terrain—still presents many unsolved challenges.

- Anticipating and exploiting enemy human reactions/responses.
- Avoiding overly predictable routines from autonomous platforms.
- Optimising autonomous employment in line with the nuances of commander's intent.

The ongoing need for reasonably close supervision directed the designed size and structure of the SACT sections. Should greater than anticipated improvements arise it is a reasonably straightforward matter to scale and adjust the structures as required.

As briefly discussed earlier, the syndicate understood that autonomous platforms and systems would be capable of functioning as a 'teammate'. That is, performing a reasonably narrowly defined task (such as moving to a location and establishing a base-of-fire against a given area) largely independently, with supervision and limited guidance from human operators. Within this is basic elements of optimisation in terms of route and position selection, concealment, fields of fire, etc. The ideal-state considered by the syndicates assumed that autonomous platforms could perform in a manner loosely comparable with a human operator undertaking basic tasks.

There remain a large number of known and unknown challenges in this space. Beyond the basic competence of autonomous systems, building effective trust within and without presents an immense challenge. Some of these considerations are discussed later, but the size and complexity of this debate is far beyond the scope of this report.

2.3.5. Logistics

Given the substantial increase in logistics footprint required by SACT, a commensurate expansion of the underlying logistics and sustainment system is also required. The expansion of platforms included in a SACT and the many accoutrements of SCS soldier suite also expands the immediate sustainment requirements per section. Armed UGVs employed in direct engagement will likely have some surplus capacity that aids carriage and power requirement; but far greater capacity is no doubt necessary.

The further addition of UGVs offers a solution to these challenges. UGV logistics sleds and possible medium to large cargo UAVs were considered for the role. UGV sleds afford the best solution due to their greater carriage capacity, endurance, resilience, and lower signature.[27] The syndicate viewed approximately one-to-two sleds per section as appropriate. Overall capacity within the PL can be dynamically allocated subject to needs, with PL HQ holding some additional UGV sleds to better facilitate resupply and flex capacity.

[27] Milrem's 'THeMIS', Rhinemetall's 'Mission Master', and Boston Dynamics' 'BigDog/WildCat' were used as indicative examples of tracked, wheeled, and legged options respectively.

UxS supported logistics can extend to the rear areas as well. The syndicate considered the widespread adoption of automation throughout the full logistics chain as feasible and advantageous in increasing overall capabilities, as well as further reducing personnel requirements. Automated platforms with armed UGV escorts could sustained multiple lines of logistics support simultaneously, achieving resiliency and redundancy. Utilising comparable or matching platforms for both logistics and combat operations would have the additional benefit of streamlining procurement and sustainment factors across a large fleet of UGVs.

Also considered were cargo UAVs offering smaller capacities with faster response times. These are best suited to rapid and critical resupply rather than carriage and bulk resupply for obvious reasons. A small number held at PL HQ would be advantageous, but not essential given the increased carriage capacity within each section and the ability to dispatch UGV sleds between sections and PL HQ for resupply.

A further element of the logistics challenge posed by the SACT is the considerable need for in-field power generation and supply. This is essential to sustaining an energy-hungry force such as the SACT. The aid of logistics UGVs relaxes the carriage constraints—somewhat—allowing for a larger generation and storage platforms within each section. The syndicate considered multiple promising technologies that may address this requirement within the 2030+ timeframe. Hydrogen fuel cells, for example, offer considerable promise given their low heat, noise, and provision of water as by-product. Whatever the specific technology, the syndicate assumed a ‘mothership’ like capability within each section’s logistics capability providing additional energy as needed to the various platforms and systems.

2.3.6. Civil-military co-operation (CIMIC)

Despite the shift towards autonomous systems and platforms, the need for human operators in immediate proximity to the close fight is not diminished by the presence of UxS. In addition to the need for responsive local supervision for autonomous systems/platforms and the presence of immediate command authority, many other tasks will still require direct human involvement. The syndicate identified CIMIC as one such priority. The absence of relatable human actors would severely diminish the critical capability to establish a rapport with local populations and manage potential prisoners to the point that human absence would fundamentally undermine key tactical and operational capabilities. This simple reality underscores the continuing need for close human presence.

Several components of the future solider suite aid in these tasks. Specifically, facial recognition, gait and body language interpretation, and on-board translation capabilities. Where strong communications with higher echelons are feasible, expertise and analytical support from the rear could also be directly provided.

2.3.7. Nine-line/starlight/casualty evacuation

Future battlefields are unlikely to be as favourable for easy or low-risk casualty evacuation as recent deployments. The probability of increased threat to evacuation platforms presents a significant challenge for casualty management. The syndicate considered two possible measures to address this.

First, SCS solider suite includes measures such as integrated tourniquets and medical monitoring capabilities. These enable swifter diagnosis and initial stabilisation of casualties in the field. Also considered were the possible application of telemedicine or some form of minor semi-automated surgery to aid in stabilising casualties quickly in the field.

Second, the syndicate considered the use of a cargo-sized UAV for casualty evacuation purposes. An indicative present-day example is the Joint Tactical Aerial Resupply Vehicle (JTARV). This platform is capable of moving 360kg approximately 200km at 90km/h. Adapted to purpose, one or more JTARV-like platforms carried on the section's logistics UGV sleds then dispatched to evacuate wounded individuals on-demand, increases the responsiveness of casualty evacuation and removes much of the risk to other assets and echelons in the process. However, the success of this approach would depend on effective stabilisation prior to lift, would not provide medical aid while in transit, and would be largely unprotected while traveling.

3. FORCE STRUCTURE & IMPLICATIONS

3.1. From / To Paradigm Shift

Syndicate discussions developed the following 'from-to' matrix capturing the key points of paradigm shift.

Table 2. SACT From/To paradigm shift. Items in Bold are those considered most significant amongst the syndicate during discussion.

Shifting From…	…To
Human teams	**Human-machine teams**
Mechanical	Data
Close human combat	Close machine combat
Close order	Dispersed order
Direct fire weapons (with lesser range)	Layered precision and at greater ranges
3:1 offensive operations ratio	**1:3 offensive operations ratio**
Low signature	High signature
Simple decoys	Multi-spectral decoys and/or complete decoy formations.
Human cognition	AI + assisted high tempo decision making
Casualty averse/scarcity mindset	**Attritable/abundance mindset**
Limited area of influence and control in complex terrain	Monitor / control larger areas of complex terrain.

Summarising the overall paradigm shift, and largely reiterating the discussions above, SACT focuses on a transition from human-centric close combat operations to a supervised-machine-centric model, with human operators remaining in relatively close proximity to the close fight but preceded by extensive UxS assets which perform much of the higher-risk tasks. As such, the human role in close combat shifts towards supervision and guidance first and direct engagement second.

In addition to the direct addition of substantial extra mass and firepower at the section level, significantly increased SA/ISR grants a substantially different level of information on the battlespace. Combining the two enables exploitation of the greater risk tolerance attached to UxS and reduced risks to human operators to permit fundamentally different tactical approaches to close combat operations. One such possibility identified by the syndicate is a mild abundance mindset, which suggests an almost a complete inversion versus present day approaches to close combat.

3.1.1. Force structure

As noted in the overview, the SACT concept centres on the integration of UxS at the section level. Scaling the concept up to the full CT sees the basic structure of the section repeated. The broad strokes of existing overarching CT structure remain similar to present day structures with relatively minor alterations leveraging the extensive use of UxS and providing the necessary support. Specifically, a SACT CT:

- Retains structure of three sections to a platoon and three platoons to a CT. Other scales (principally a larger number of sections) and structures (flat structures by removing PL HQ) were considered, but existing structure was deemed both suitable and advantageous given assumptions about supervision and cognitive load.
- Sections are comprised of two mirrored fireteams. Each features a fireteam sub-commander and two specialists, one each for platforms (UGVs) and systems (ISR/combat cloud). Each fireteam can take a portion of the section's UxS assets and function independently, providing further flexibility.
- An Autonomous Fire Support Section (AFSS) - comparable to a MSS - provides self-deploying mortars, heavier loitering munitions, and other heavy weapons as appropriate. An AFSS falls under each PL HQ, equipped with three medium UGVs fitted accordingly.
- CT HQ holds a further collection of armed med-UGVs controlled by the CSM for employment as needed.
- Generally, most CT HQ roles remain comparable to the present but with reduced personnel in most areas given the increase in autonomous and integrated systems alleviating some of the need.
- The exception is Signals that expands in light of the considerably increased demand in terms of C2 and offensive/defensive EW and cyber. Other related tasks, such as the recovery of enemy platforms for data/intel extraction and exploitation, will also require additional specialist personnel.

The figures below offer an indicative overview of the SACT concept from section through to CT.

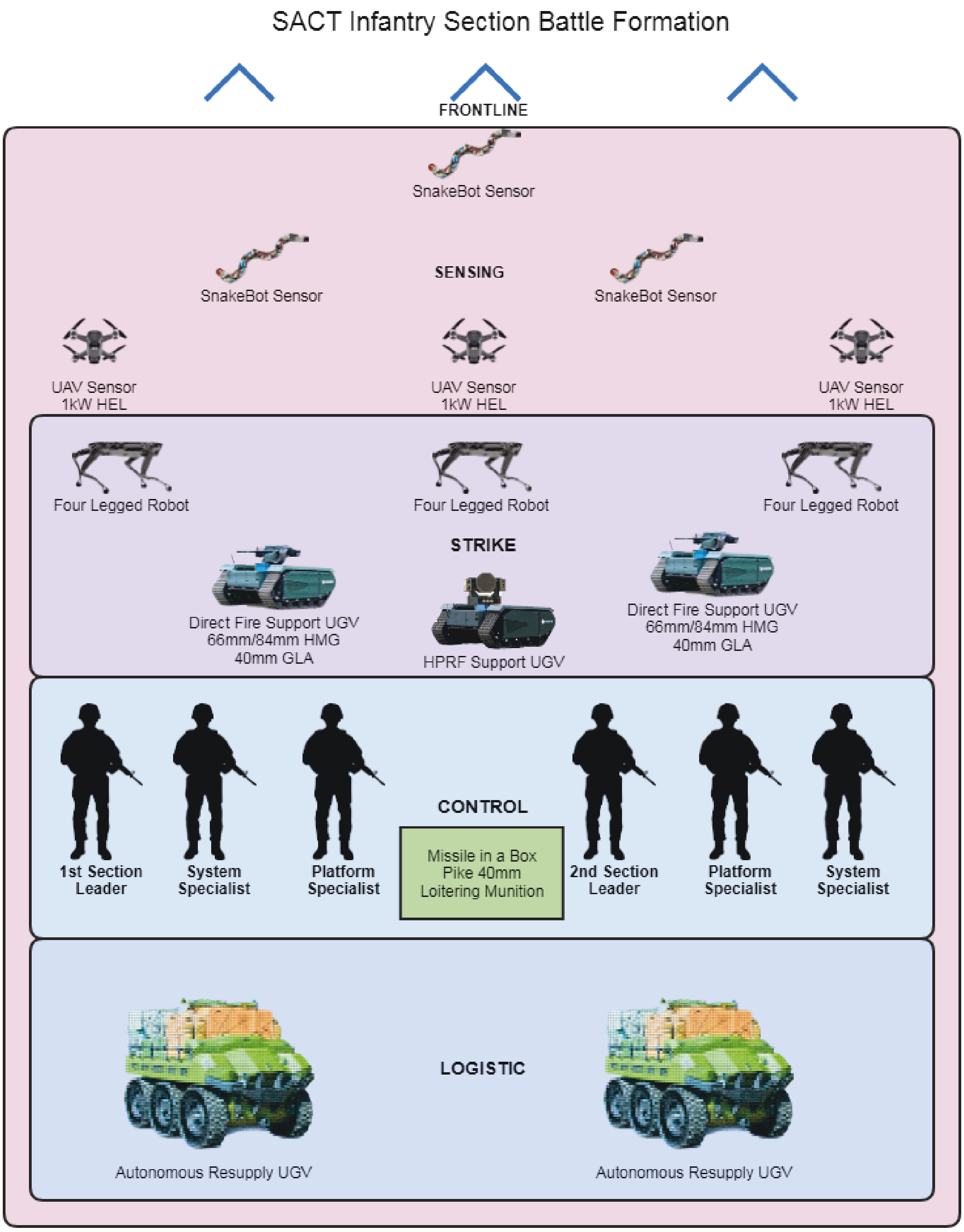

Figure 6. SACT section-level arrangement and indications of UxS employment outwards from the human core of the section

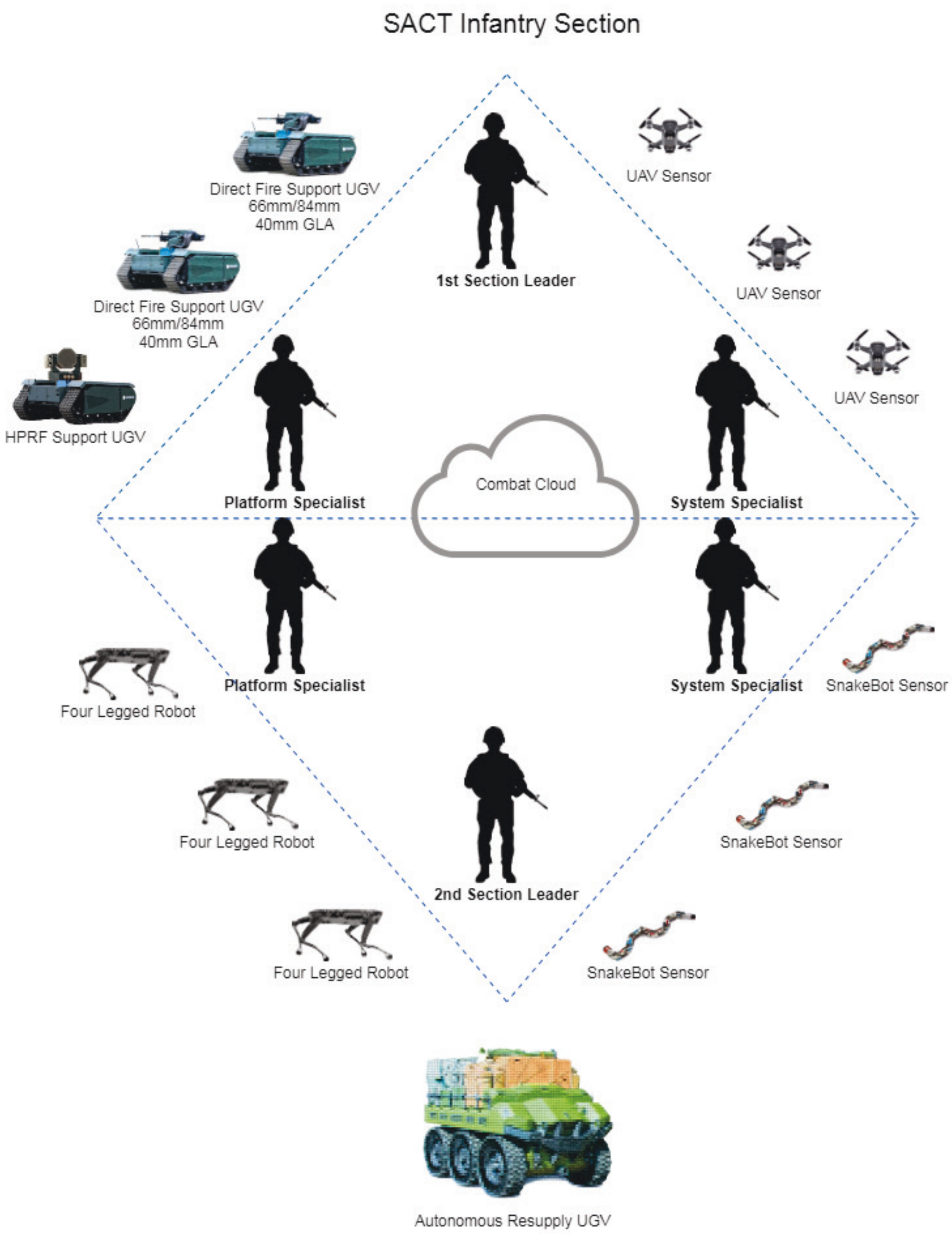

Figure 7. SACT organisation at section level, indicating UxS employment.

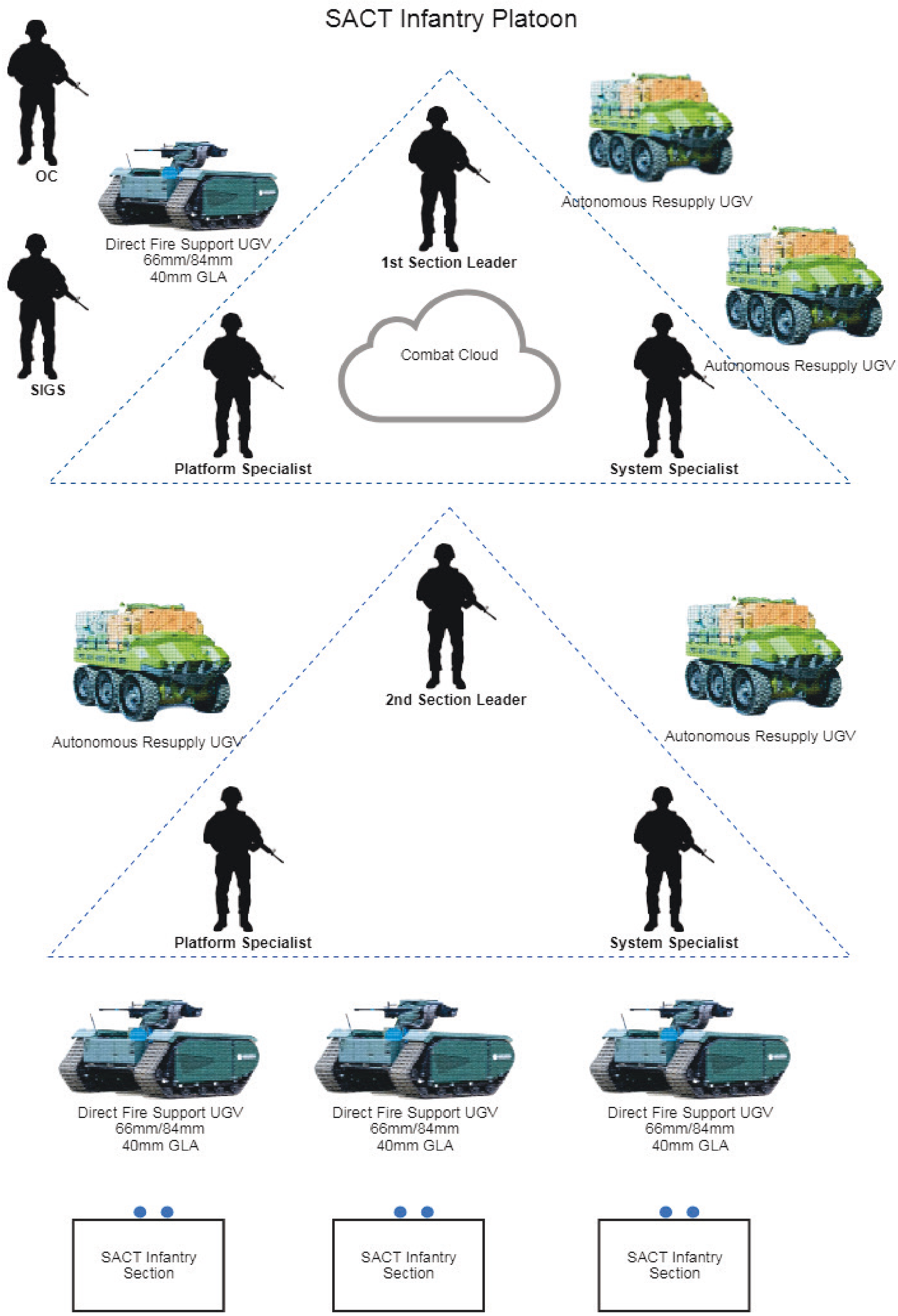

Figure 8. SACT Platoon HQ organisational level, personnel, and additional supporting UGVs

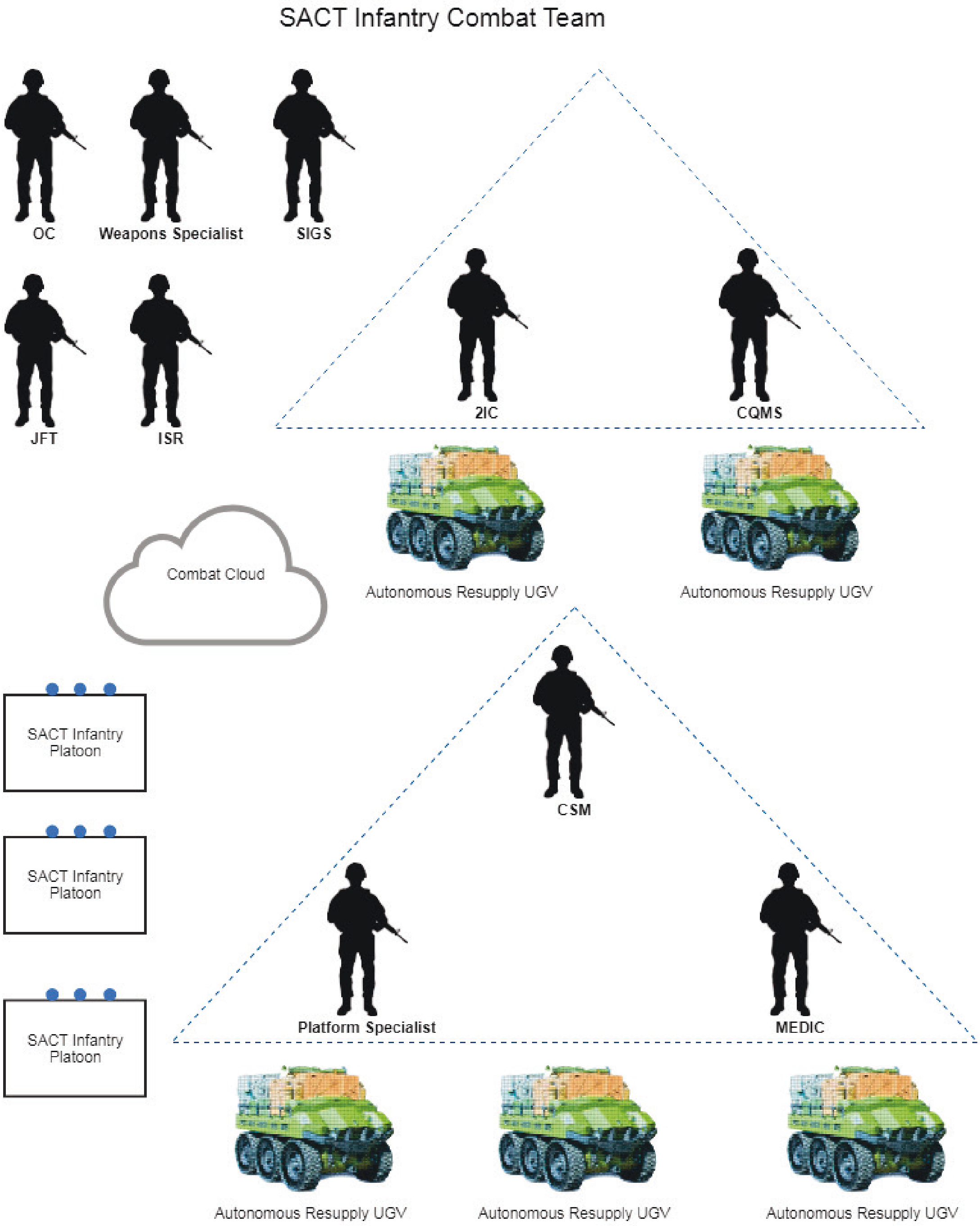

Figure 9. SACT CT HQ organisational level, personnel, and additional supporting UGVs

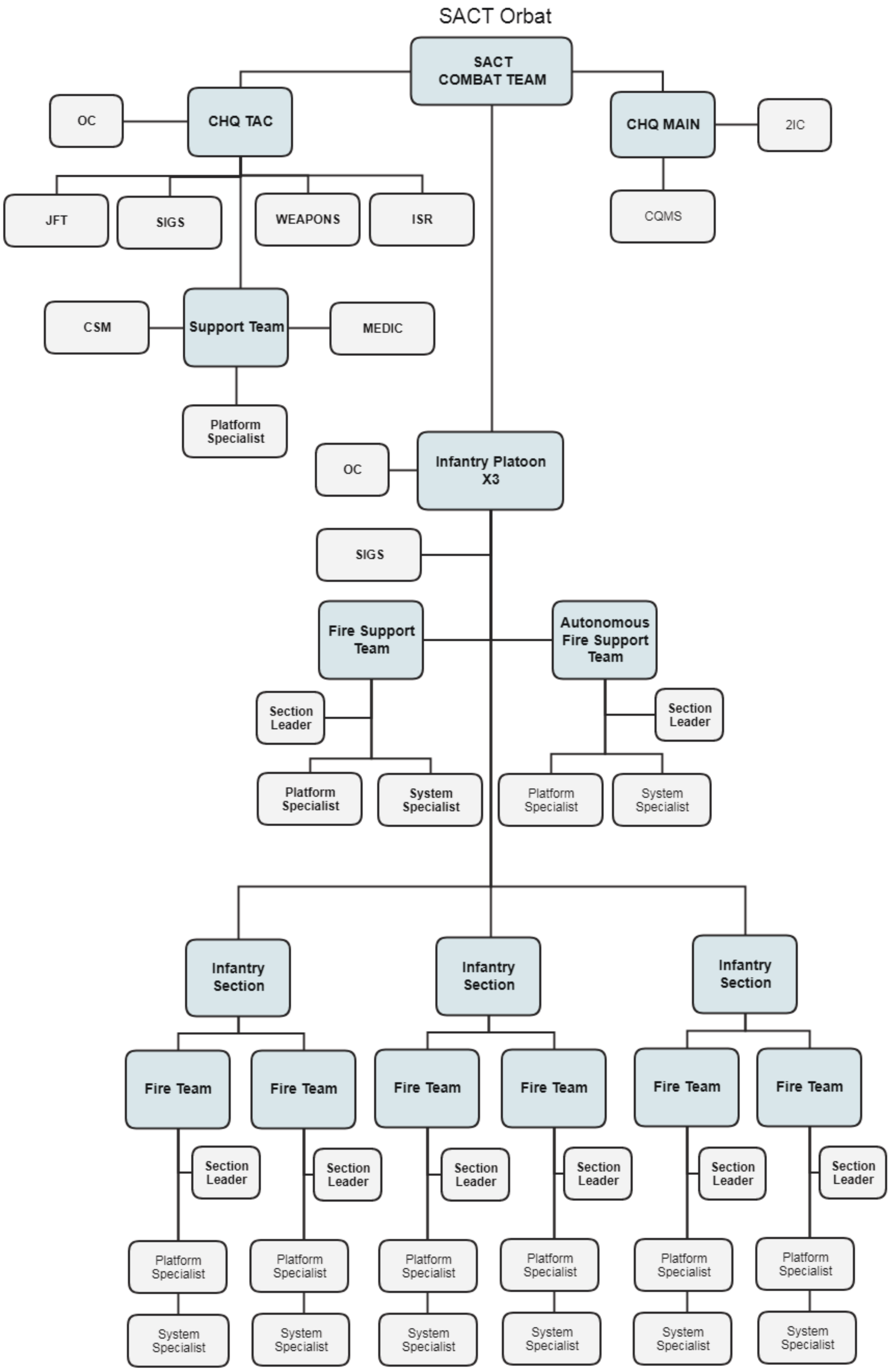

Figure 10. Semi-Autonomous Combat Team indicative ORBAT. Note, only one Platoon illustrated in detail.

Table 3. Indicative SACT personnel breakdown.

	CT HQ	PL HQ	SECT
	1 – OC	2 – Command and sigs	6 – 2 fireteams of 3 e.a.
	1 – 2IC	3 – PL HQ Sect	
	1 – CSM + UGVs	3 – AFSS	
	1 – Wpn SGT	18 – 3 Sections (6 e.a.)	
	2 – JFT		
	1 – CQ		
	1 – Starlight		
	6 – Sigs		
	78 – 3 Platoons (26 e.a.)		
TOTALS	92 per Combat Team	26 per Platoon	6 per Section

3.1.2. Brigade implications

There are a wide range of Bde level implications stemming from the SACT concept. The following are several notable elements highlighted during syndicate discussions.

Logistics, Lift, and General Mobility Support

The number and complexity of platforms involved not just in close combat, but also in the logistics backbone enabling a SACT to function results in a heavily increased demand on Bde level logistics support. There are several dimensions to this:

- Platform sustainment, including the sustainment, service, repair, and recovery of platforms engaged in combat operations.
- Generally expanded logistics footprint
- Energy generation and supply.
- Resupply and/or field manufacture of attritable platforms such as Breachbots and ISR platforms.
- Security for the expanded logistics footprint.
- High-level support for the capture and exploitation of adversary systems for intelligence product and general exploitation.

The presence of a highly mobile and capable field workshop at BDE level capable of advanced 3D printing is highly advantageous to supporting SACT in the field. The syndicate considered this a major requirement given the scale and number of demands generated.

Energy generation and supply in particular presents a major challenge. Though increased carriage capabilities within each section facilitated by logistics sleds enables greater in-field generation, ultimately the fuel for in-field systems and sustainment burden of the wider logistics network is considerable, and falls at Bde level.

Similarly, the increased number of platforms conveys a demand for increased lift and general mobility support. Though the parameters of the design process imposed reasonable limits to preclude excessive lift demands, the number of platforms and expanded logistics chain will tax existing Bde level support. The addition of automated air and ground platforms and may aid considerably in this area, at the expense of further increasing the reliance on autonomous systems.

Engineering and combat mobility support

The addition of a significant number of UxS platforms expected to manoeuvre through complex terrain will require substantially more engineering and mobility support compared with human-only sections. Similarly, the advent of plentiful breachbot-like platforms are unlikely to be exclusive to friendly forces. Similarly, 'smart' minefields capable of self-healing and improvised obstacles will impose additional demands for engineering and mobility support from BDE. Though advances in autonomy and improvements to the platforms themselves—particularly soft-robotics and legged platforms—will no doubt alleviate some of this demand, increased engineering and mobility support is essential.

Signals and Cyber

Extensive use of UxS platforms, complex networked computers, and extensive digital communications throughout a SACT implies an expanded need for Signals and Cyber support from BDE. Similarly, the future operational environment is highly likely to be replete with civilian networks, sensors, actors, and their accoutrement. Engaging with these is essential. This encompasses three pressing areas:

- The need to secure friendly systems and networks against adversarial efforts, including EW and cyber.
- Offensive cyber, signals, and EW actions against adversary digital systems and networks. Including the monitoring of any surviving civilian networks in the area for intelligence insights.
- The increasingly pressing need to engage with and win over civilian populations within the area and internationally, as part of Defence's contributions to whole of government efforts.

Each of these requires substantial skill, expertise, civilian interfacing, and wider awareness that is best situated at BDE level and above, with reach downwards into the CT as required. Some level of autonomy, AI/ML, and data fusion may be achievable in support of these tasks within the 2030+ timeframe. Nevertheless, the increased scope and demands on these will likely demand greater support both within and without of the CT.

Joint Effects and Fires

Despite the increase in organic capability down to the section level, a need for fires and effects from higher echelons and other domains will endure, requiring coordination and support at BDE level. However, as with the CT HQ level denoted above, the addition of the future soldier suite including combat cloud streamlines the process and reduces some of the burden in facilitating joint effects and fires.

Ground Based Air Defence (GBAD)

A key point of weakness identified by the syndicate is the relative lack of GBAD within the CT, especially in a future environment permeated by airborne platforms. The option for 1kW and 50kW fitted to UAVs and UGVs respectively offers some improvement in capability in managing low level threats, as does the employment of smart fire control systems on other UGV weapon platforms adds some ad hoc capability ideally capable of mitigating some less sophisticated threats. The combination may achieve some level of local IADS capable of mitigating the immediate threat from enemy UAVs; however, an overriding threat from the air remains. Especially in light of the rapid public and private development in the area. Substantial BDE support is necessary to deter or defend against those threats.

4. PERFORMANCE EXPLORATION

4.1. Identified Risks & Issues

The syndicate identified a range of noteworthy risks associated with the SACT concept, and wider nature of the advanced engagement space.

Autonomy

SACT heavily features various forms of autonomy, and with it, an equally heavy dependence on trust in that autonomy to function as intended rather than as feared. On a technical level, the development and deployment challenges attached to autonomous systems are immense and still require extensive effort to reach the levels of maturity sufficient for a SACT-like concept. Early signs are promising, but the synthesis into a cohesive whole that can be integrated as a 'teammate' up to human standards is still some distance away.[28]

Technical capability aside, the very nature of autonomy and introducing the manners and types of autonomy discussed here into combat operations is fraught with moral, ethical, legal, and political dilemmas. Assuming the technical hurdles are cleared sufficiently, the trust-building process is likely to be lengthy and troublesome. The risks, issues, and potential pitfalls in this area are recognised widely enough to have prompted significant international campaigns calling for bans on the development or use of autonomous 'killer robots'.[29] Similar debates also surround the comparatively tamer subject matter of driverless cars, as well as a host of other related fields.

Interestingly, a similar model of supervised autonomy in the defence context is already widely accepted and in use today – point-defence CIWS & C-RAM. As with the SACT concept, constant direct human control is not feasible due to the nature of the environment, and the speed of events, and the number of platforms and targets. Instead, accepting a level of supervised autonomy within carefully established bounds enables the benefits of autonomy while retaining appropriate levels of control.

The design of SACT presents a model of supervised autonomy in response to these challenges. By retaining immediate on-site supervision of autonomous platforms, not only are efforts better coordinated but also many of the moral, ethical, and legal issues are at least partially defused. Humans may not be 'in-the-loop' but they remain 'on-the-loop,' able to closely constrain and monitor behaviour of platforms to ensure appropriate conduct.

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[28] It should be noted that actors less constrained by moral, ethical, legal, and political bounds could construct a simple version of these systems essentially today. Albeit at the cost of a much higher probability of error and without the benefits of the close supervision and constraints featured in the SACT concept.
[29] See, for example, The Campaign to Ban Killer Robots (https://www.stopkillerrobots.org/).

Meanwhile, the nature of autonomous systems promises greater consistency in decision-making as they are unclouded by fatigue and freed of some of the unpredictability inherent to human cognition under stress. The combination of close supervision with autonomous endurance, traceability, and consistency potentially offers the best of both worlds.

The nature of and need for a nuanced discussion of these challenges is far beyond the scope of this report. Suffice it to say, consideration of these issues helped shape the SACT concept. Nevertheless, the path and nature of autonomy and delegation represent major issues with inbuilt risks that are intimately attached to the SACT concept. The viability of the concept requires the effective management and/or resolution of these issues.

Cyber and EW Vulnerability

As noted in the BDE implications section above, SACT carries with it a heavy reliance on UxS platforms, computer systems, and communications. This goes beyond simple additions to capability. The reliance strikes to the level of core functionality. Without those systems and linkages, the CT fails to function and its human elements will find themselves overextended and overmatched. Given this, it is certain that adversaries will endeavour to threaten, degrade, or deny that functionality through cyber and EW.

Of particular note in this respect is the likely presence of HPRF weapons on the future battlefield. These pose significant risk to a UxS dependent force such as SACT. Heavier shielding against weaponised HPRF is feasible for the larger platforms—affording some resiliency—however, SWaP constraints preclude effective shielding for the smaller and lighter UxS platforms in the Sensing Field. The consequence is that a well-timed and coordinated HPRF strike threatens to blind or destroy SACT's ISR system, while also temporarily disrupting its key engagement capabilities in the form of combat cloud, armed UGVs, loitering munitions, and PGMs. This threat type was explored during the brief wargaming component towards the end of the workshop process and represents an enduring tactical challenge inherent to the adoption of unmanned systems.

Responding to these risks will require an extensive effort developing suitable TTPs alongside a persistent and highly skilled reach back capability for cyber and EW support. This will necessarily include deep links to the civilian world. This is likely to present a major challenge in terms of meeting the organisation and tempo requirements to achieve effective security. This cannot be a crunch effort. Cyber security requires a substantial and standing commitment to aggressively maintain robust systems and respond quickly to vulnerabilities as they are discovered. Effort at this level will likely prove challenging to establish, maintain, and justify in peacetime – despite its essential nature.

The worst-case scenario sees an adversary seize control of friendly UxS through cyber means, turning them against friendly forces and/or civilians to disastrous effect. This would be catastrophic at the tactical, operational, and strategic layers for obvious reasons. Even less severe scenarios featuring the subversion of trusted systems, such as combat cloud, the Sensing Field, or the targeting constraints on autonomous engagement systems, could lead to horrific results with immense moral, ethical, legal, and political ramifications. Enemy action in these areas is often difficult to recognise ahead of time, and extremely challenging to prove conclusively to outside parties – particularly aggrieved parties.

Cognitive and Human Demands

SACT's emphasis on supervised autonomy requires a fundamental shift in the mindset and capabilities of human section-members. The need to track several platforms or clusters in real-time, coordinate their activities, and reach out through them to achieve battlefield effects is no small task. Cognitive demands were factored into the design through approximate assumptions on suitable supervision levels and cognitive enhancement options, such as via pharmacology or neurological computer interfaces, were considered during the syndicate's discussions. However, while these potentially alleviate the problem, they cannot solve it.

A key dimension identified in managing workloads and cognitive demands is underlying interfaces and systems. Put simply, intuitive, effective, and easy to use UX design is essential to the practical success of combat cloud, the future soldier suite, and the wider SACT concept. Without accessible and user-friendly controls, the tempo and engagement benefits of the concept are lost, while the cognitive burdens, training demands, and risk of grave errors increase dramatically.

Also broadly considered were AI decision support platforms. However, due to the ambiguity surrounding their role, effectiveness, and readiness within the established 2030+ timeframe, these have been largely excluded from this report. Suffice it to say, should they become available they may provide significant benefits to the SACT concept.

Signature Management

Given the dramatically increased number of platforms included in SACT and the probability of sensor saturated future battlefields, remaining entirely unobserved is highly unlikely. Instead, nuanced signature management, EMCON, decoys, deception, appropriate TTPs, and a careful dance within the detection threshold is required.

As the presence of a SACT enabled section is near impossible to hide due to the number and passive emissions of the various platforms, the challenge becomes ensuring that its signal is sufficiently ambiguous to preclude effective targeting. In other words, operating above the general detection threshold, but critically below the targeting and firing thresholds.

UxS systems combined with increased standoff they enable are key to accomplishing this. By leveraging the extended ISR screen, other SACT assets can—hopefully—remain sufficiently distant to mitigate direct detection. In the (likely) event that some platforms are detected at some point, the overall distribution of a SACT section is sufficiently deep and distributed that its precise location remains ambiguous. As firing on the partial detection would also unmask and expend the engaging platforms, also inviting return fires, this is not a decision taken lightly without an expectation of a meaningful effect. With appropriate TTPs, SACT aims to exacerbate this dilemma by making the detection necessary for a single decisive strike more difficult to achieve, forcing Red to either hold fire or adopt disproportionate levels of risk or munitions expenditure to achieve meaningful effects. This is obviously heavily contextually dependent and relies on the deterrent threat of effective counter-fires from Bde and above.

A simple analogy comes from submarine operations. Indications of presence alone are not sufficient to achieve a targeting solution against a submarine, let alone identify it. A SACT section aims to straddle the line between detection of its forward elements that indicate general presence, and a targeting solution against its core assets – i.e. its human members and logistics platforms. Within this spectrum of ambiguity, and with the aid of UxS platforms, there is ample scope for decoy and deception tactics. From decoy emitters at the shallow end, to full replica (or even actual duplicate) formations of SACT sections, the combination of ISR, standoff, and attritability enables a number of potential avenues.

Cost and Sustainment

Though noted above when discussing BDE implications, the scale and nature of the logistics dimensions to SACT bears further mention beyond the BDE context. Simply put, a SACT is large and expensive to develop, establish, maintain, and deploy. Setting aside the increased size and scale of the logistics footprint, the budgetary implications of adopting this model are sizable, even with the benefits of less-exquisite, affordable platforms supported by 3D printing and cheaper-still attritable platforms. SACT primarily achieves its benefits to lethality, survivability, and general capability through this expanded cost burden. However, this level of expenditure may prove difficult to justify amidst the wider host of equally pressing defence priorities.

Furthermore, the components of SACT are likely to change rapidly as time progresses and adversaries adapt. This is the reality of the future advanced engagement environment, where rapid adaption and readily available COTS technology combine to outpace defence procurement cycles typically measured in decades.

4.2. Performance against Scenarios Classes – Wind Tunnelling and Wargaming

The syndicate employed a brief tabletop wargame to better explore SACT's strengths and weaknesses. This saw a SACT undertaking a clearance operation based on the Urban Battlefield Marawi scenario. Red consisted of a state-backed hybrid force, with specialist advisors and the select insertion of key technological capabilities (primarily 1-shot HPRF generators, general weapons and munitions, commercial-grade UxS, and various ISR platforms). A substantial number of civilians remained within the city, kept there either by force or through loyalty to Red's cause.

The wargame method was a two-sided discussion with self-adjudication along 'action, reaction, counter-action cycle' lines. Blue held the initiative to begin, though not surprise as red had ample time prior to prepare the environment with plans, prepared defences, and pre-positioned assets.

The course of the wargame provided several observations on the SACT concept:

- It supported expectations of increased effectiveness down to the section level. Sections and the SACT as a whole could undertake larger mission-sets and monitor/secure larger portions of highly complex terrain while reducing the level of risk to humans – solider and civilian – through improved ISR, dispersion, and layered engagement capability extending outwards.
- The ISR field dramatically improved awareness and sharply limited Red freedom of action, despite complex defence preparations. 'Mouse-holes' between buildings were uncovered more quickly by Blue and substantially easier to manage with the presence of plentiful, versatile ISR assets.
- Breachbots, section-level PGMs, and AFSS-provided loitering munitions provided compelling fixing effects, cut-off, and area denial. Among other benefits, this provided a defensive buffer surrounding the SACT that partially mitigated many potential Red threats (i.e. suicide vests, car bombs, etc).
- Similarly, armed UGVs aided in breaching, clearing, securing, and holding complex terrain without requiring high-levels of human risk.
- However, the high demand for engineering support and breaching capabilities rapidly outstretched available capacity, further highlighting the demands placed on BDE level engineering and manoeuvre support.

The wargame also highlighted several areas where Red can exploit similar technologies to threaten a SACT element:

- Red also seized upon the technological opportunities presented by UxS, including their own swarms of suicide/breach-bots. These were employed to achieve area denial, frustrate clearance operations, control civilian populations, and integrated into complex layered ambushes. This points to a pronounced role for skirmishing between UxS assets and the need to engage/defeat small UxS swarms as far out as possible.
- Plentiful ISR platforms, though less sophisticated and without sensor fusion, enabled Red to track the general location of Blue – despite counter ISR platforms, TTPs, and Blue HPRF employment. Though the nature of the task operating in Red prepared terrain make this somewhat unavoidable, with or without improved ISR assets.
- Technology inserts (principally HPRF) enabled Red to heavily attrit and disrupt Blue's Sensing Field and UGV platforms in tandem with layered effects and a booby-trapped building. Though human losses were minimised, the loss of its UxS platforms quickly fixed the ambushed section and sharply undermined their combat effectiveness given the small number of soldiers present. This robbed the SACT of any initiative while it recovered.
- This event prompted a further discussion on the depth of SACT replenishment of autonomous and attritable systems. How many replacement platforms would be readily available, and how quickly could they be deployed? How long could large-scale losses of UxS be sustained before a SACT suffered sharp reductions in effectiveness? The smaller number of human soldiers would rapidly find themselves overextended and overmatched without UxS support.
- Red also leveraged civilians to induce targeting dilemmas, straining supervision requirements, creating many possibilities for costly error, and precluding the free usage of PGMs and other heavier weapons – despite the improved ISR and presence of smart fire control systems.

Overall, the wargame component provided a good, if brief, test of the SACT concept and highlighted several strengths and weaknesses.

Particularly noteworthy was that the syndicate considered tasking a conventional (i.e. present-day) CT with the same task against the future-equipped Red in the Marawi scenario non-viable. A present-day CT would likely be incapable of entering the city within acceptable risk tolerances and would face severe threats from an improved Red if they did, given improvements to Red's ISR, availability of HPRF systems denying electronics and communications equipment, and extensive exploitation commercial-grade UxS platforms.

These observations suggest that—whether in the form of a SACT-like or alternative approach—the adoption and deep integration of new technologies and systems down to section level is essential just to keep pace.

4.3. Metric Judgement

The concept was self-assessed (Table 4) against a metric objective framework on its ability to deliver the required capabilities and effects in the Jungle Battlefield Borneo vignette and the Subterranean Battlefield Toronto vignette. A 5 point Likert scale from 1 (no capability) to 5 (fully capable) was used.

Table 4. SACT Concept Performance Assessment

	Vignettes	
Objectives	**Borneo**	**Toronto**
Respond to challenges in surface and super-surface urban environments	4	4
Respond to challenges in interior and sub-surface (subterranean) urban environments	5	5
Respond to challenges in non-urban environments e.g. jungle, mountain, desert, riverine, etc	5	5
Respond to challenges to the cyber domain including the EM environment	2	2
Respond to changes in the intelligence picture and situational understanding	4	4
Employ a resilient and persistent close combat capability	5	5
Employ an adaptable and flexible close combat capability	5	5
Perform reliable sustainment in the operational environment	3	3
Outlast adversaries in combat	3	3
Maintain freedom of action throughout the engagement	4	4
Maintain defensive advantage and gain offensive advantage	4	4
Apply a compressed kill chain in close combat	5	5
Identify real-time operational environment effects	4	4
Achieve decisive tactical effects	4	4
Outperform the adversaries by exhibiting physical, cognitive, social and cultural resilience	3	3
Synchronise all effects necessary to generate warfighting advantage	5	5
Outsmart the adversary in combat	4	4
Demonstrate leadership, flexibility and adaptability in combat	5	5
Adopt "conditions" command and decentralised decision making when needed	5	5
Identify and exploit potential sources of friction in battle	3	3
Open up constraints in the operational environment	4	4
Control the performance, reliability and security of information networks	3	3

Overall, the syndicate rated the SACT concept reasonably highly. Key weaknesses identified during this assessment largely follow from those discussed above, notably logistics, endurance, and cyber/EW threats given the platform dependencies that are inherent to the overarching concept.

Ratings for the two vignettes considered did not vary substantially, or vary much between participants. This is unsurprising as the SACT concept was designed around the forms of complex terrain considered and benefited from thorough discussions that arrived at sound consensus among the syndicate during the design phase. In both cases the versatility of SACT, including its ISR assets, presence of UGV engagement platforms, enhanced lethality, and improved survivability, enable a SACT to operate effectively despite the challenges of complex terrain and adversarial forces.

However, consideration of the Toronto scenario did further highlight the complexities of highly built-up urban environments, particularly:

- The myriad threats to friendly air assets combined with the reliance on BDE for matching air defence when above ground.
- Difficulties clearing the sheer number of rooms and floors in high-rise buildings attached to Toronto's 'PATH' network. Smart-dust MEMS ISR was rated highly in this niche due to its ability to rapidly utilise ventilation systems. While this does not remove the challenges of clearing dense, vertical urban environments, it does improve visibility and streamline the task.
- The increased prospects for UxS attrition in these environments, particularly subterranean complexes comparable to the 'PATH' network.
- The challenges ensuring communications even at section level in complex urban terrain. Platforms capable of operating with asynchronous data flows combined with data ferrying 'carrier pigeons' or 'breadcrumb nodes' would rapidly become invaluable under these conditions. i.e. a small UAV providing periodic tasking and awareness updates in the absence of direct and/or timely communications.

5. CONCLUSION

A Systemic Design methodology was employed to develop post 2030 dismounted infantry concepts to prepare Army for advances in sensing, precision attack, and decision-making that will fundamentally alter the character of future conflict engagements. The outcomes of the study informing the long-term development of the Soldier Combat System Program (SCSP) and associated capabilities.

The concept described in this report, the Semi-Autonomous Combat Team emphasises the integration a variety of unmanned systems (UxS), primarily aimed at substantially boosting capabilities at section level. This takes four main forms:

- A multi-platform, layered, self-organising, persistent field of sensors.
- Armed small/medium-UGV platforms equipped for direct engagement and fire support, capable of semi-autonomous movement & engagement.
- Small indirect capabilities organic to the section (PGMs and loitering munitions), with larger variants available at platoon level. Enables precision engagement and loitering cut-off on-demand without reliance on other echelons.
- Attritable 'breachbots' capable of undertaking high-risk roles, such as initial assaults, or achieving 'smart' area-denial.

These various platforms are linked, controlled, and cued via a 'combat cloud' located and operated within the section providing responsive and reasonably assured C2 for the large number of UxS, along with an immediate locus of supervision. Although the ISR and UGV systems are capable of semi-autonomous operation, supervision remains necessary within the timeframe and as a safeguard ensuring LOAC compliance. UxS platforms move ahead of the section's human members, as they supervise and direct the various platforms to coordinate their efforts. Figure 1 illustrates the arrangement in broad terms.

The presence of a persistent, adaptive, and largely self-managing ISR field affords far greater awareness of the battlespace and facilitates cued engagement at-will within its coverage. The other UxS platforms then offer the section a robust and layered set of direct and indirect engagement options providing considerable overmatch compared to a conventionally equipped section. Combined, the ISR field, armed UGVs, and organic indirect fires enhance engagement capability and lethality significantly across and extended standoff gap facilitated by the ISR field. Human section members, meanwhile, in effect, act through their UxS platforms first, before assuming risk themselves.

Self-assessment and tabletop wargaming of the concept revealed:

- Support for the estimated improvement in offensive operations ratio. The additional awareness, fires, area-denial, reconnaissance, and direct engagement capability achieved either parity or overmatch against the considerable challenges presented by a 2030 Marawi scenario.
- The ability to enter and operate effectively and achieve overmatch within actively contested and defensively prepared complex urban terrain where a conventional CT could not without unacceptable risk.
- Significant resilience when ambushed, assaulted, or otherwise engaged by asymmetric threats (VBSIED, for example). However, this comes at the expense of expending attritable and semi-attritable platforms that equates to reduced effectiveness while awaiting/undergoing replenishment.
- A vulnerability to high-energy HPRF engagement. One example explored proved sufficient to fix the CT's human members in place and sharply curtail their awareness and effectiveness, given the probable degradation or loss of a large portion of the ISR, engagement platforms, and individual solider equipment.

Perhaps most telling, the concept recognises that technology insertion and incrementalism is inadequate and features deep levels of adaption and paradigmatic shifts in response to the future operating environment.

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