13th ICCRTS
"C2 for Complex Endeavors"

Title of Paper: Designing 'Killer Applications' of NCW – A process to support creation and innovation

Topics:
Network-Centric Experimentation and Analysis
Collaborative Technologies for Network-Centric Operations
C2 Concepts, Theory and Policy

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Abstract

Research on Network-Centric Warfare (NCW) has largely focused on the development, implementation and impact of the supporting technical network. However, there are very few published examples of war fighting advantages arising from NCW perspectives, particularly of paradigm changes in warfare arising from innovative, network-centric concepts.

This paper presents initial thoughts on a process for developing network-centred concepts for the future military, from case studies in the Australian context. In the authors' experience, it is not enough to develop a single concept; but necessary to articulate the landscape of possible options. The authors had to rethink their tools and thinking processes as a result, drawing upon the software development field for its experience in new product development.

1 Introduction

In *Winning the Next War*, Stephen Peter Rosen (Rosen, 1994) adopts a tight definition for "innovation" – not merely the introduction of a new technology, but one forcing the adoption of new doctrine or practice. On these grounds, NCW in 2007 is in trouble, as mooted implementations of NCW into future forces are recognisable scalings of present-day concepts. The result has been questions about the utility of infusing network-centrism into a force, with arguments about "conventional" improvements in firepower being countered with sometimes-philosophical theories about new kinds of warfare (Weiner, 2004) (Waters, 2006).

In the civilian world, the infusion of computing and networking has yielded multiple generations of innovation over the same time period as its injection into the military world: the personal computer of the 1980s and Web 1.0 in the 1990s and (potentially) Web 2.0 in the 2000s have each yielded substantial changes to the conduct of finance, education, and commodities industries, to name a few. Nor is it sufficient to claim that the defence & security world is in some sense unique – over the same time interval, stealth technology and precision weapons have been taken into high-end military forces, with the result that governments simply *expect* such militaries to be able to strike with impunity where and when directed.

This phenomenon is well known within the technology product development world – the "killer application" that draws consumers to a product, *not* on the intrinsic technical merits of the product versus its competitors, but for its extrinsic utility to the consumer (Coffee, 2007). There are, however, few examples that demonstrate NCW driving the development of innovative concepts to achieve a war fighting advantage. There are some examples of how NCW has changed work practices (eg Goehmer et al, 2004; Gonzales et al, 2005), and studies that have proposed new concepts without going into the details of how they can be implemented (eg Chim et al, 2007). The result is a sense that NCW has lost its way, with symptoms including the statement that "NCW does not require its own specific doctrinal products" (Department of Defence, 2007).

The authors have, at time of writing, completed three studies that centred on the injection of networking and emergent technology into the future force to achieve step gains in capability for the future Australian Defence Force. The studies led to significant findings within the Australian Defence major investment program, as well as seeding long-range research programmes within the technology-focussed areas of

the Defence Science and Technology Organisation. We reflect on the activities that were common across these studies, illustrated with unclassified extracts. Our goal is a process that supports the generation of innovative concepts ("killer applications"), and that supports their investigation to a degree of granularity that war fighting sponsors can use in major investment decision-making, and that is reusable and sufficiently straightforward to be rapidly taken up by other researchers including new recruits and graduates.

2 Background

2.1 Methodologies

In determining the activities to undertake, the authors drew on their experience in a variety of methodologies including software and systems engineering, and hard and soft operations research. However, they found that none of these techniques were sufficient.

The methodology that most closely claims to address these types of problems is Soft Operations Research (including Soft Systems Engineering). In a wide-ranging review of the Soft Operations Research literature, Heyer (2004) assessed the suitability of these approaches to solving different classes of problem. Heyer's analysis showed that most of the techniques were useful for understanding problems, evaluating solutions or gaining agreement on a solution once a range of solutions were available. However, she did not look at their suitability for developing new concepts or identifying opportunities for exploitation.

In contrast, software development is focused on creation and development rather than the evaluation of solutions. While traditional software development approaches focus on the development of well-defined requirements prior to the commencement of coding, software developers have used techniques such as prototyping, spiral development and Extreme Programming for handling ill-defined problems (McConnell, 1996) (Wells, 2001). Common features of these approaches include:

- *Developing a product based on incomplete information*. Depending on the approach and the stage in the development process, the product may focus on solutions to known requirements or exploration of areas that are problematic either because of technical difficulty in solving them or because the problem is ill-defined. Such products are may be called Prototypes, Iterative Developments or Spike Explorations.
- *Reviewing the product*. This may include a technical review of problems that were encountered, but almost always includes feedback from the client.
- *Feedback loops*. Determining the future directions for the project, based on the results of the previous two activities.

2.2 Case Studies

Three studies of this ilk have been conducted by the authors. These studies are described briefly below.

Case Study 1. *Air defence of a deployed maritime task force*. This study looked at how a deployed ADF task force could be defended against air attack. Central to this investigation was the cueing of air defence shooters (aircraft, surface combatants) to threats (search aircraft, missile shooters), and the

support to those shooters through to successful prosecution. It determined the engagement requirements and several alternative sensor-to-shooter configurations (including information flows and command arrangements) using both national and coalition networks. These were assessed for technical and operational feasibility. This study was classified, however some discussion may be found at (Hew, 2008).

Case Study 2. *Exploiting remote sensing*. The Australian Defence Force currently has a major investment plan looking out to 2016 – the Defence Capability Plan (DCP) (Department of Defence, 2006b). Case Study 2 explored the technology changes that could eventuate during the lifetime of systems acquired under the DCP, and how they could be used to deliver improved capability in the area of remote sensing. Two different sensing technologies were considered (Case Study 2a and 2b). In both cases, the sensors are currently employed pre-mission to gather information. Their studies looked at what would be required to enable data to be collected and analysed in near-real-time for in-mission exploitation. It examined technical and organisational requirements, communications capacity, alternative platforms, and different degrees of integration with other sensors. For example, the study examined the possibility of transmitting raw imagery to single-seat F/A-18 mid-mission and concluded that even if it was technically feasible, this could overload the pilot. This case study is used in most of the examples in this paper.

Case Study 3. *Amphibious Task Force Design*. This study looked at what was required to enable an amphibious task force to achieve both interlaced and concurrent missions. It included identification of the missions and their co-dependencies, development of alternative task force configurations (including platforms and information flows) and examination of the relative strengths and weaknesses of the different configurations. This study was also classified; however some discussion may be available to TTCP participants (Hew *et al*, 2007).

3 Activities

The three case studies looked at particular injections of networking into the future, joint Australian Defence Force. The motivations varied, to include assessing the effect of changes in technologies or systems, or focussing on a particular capability deficiency. However, each of the studies focused on developing options for the integration and impact of the networked force.

While there were variations in the methodology used across the studies, the activities shown in Figure 1 have emerged as being important:

- Identifying unmet military needs that would yield a step-change in war fighting advantage if filled.
- Identifying the current "kill chain" or process model of interest.
- Identifying physical, cyber or cognitive phenomena that can be exploited through networking.
- "Spike" explorations of selected options, to de-risk the overall investigation.
- Examination of benefits and vulnerabilities of new options.

- Refactoring knowledge from "spike" explorations into knowledge about the whole system.
- Constructing a landscape of overall options.

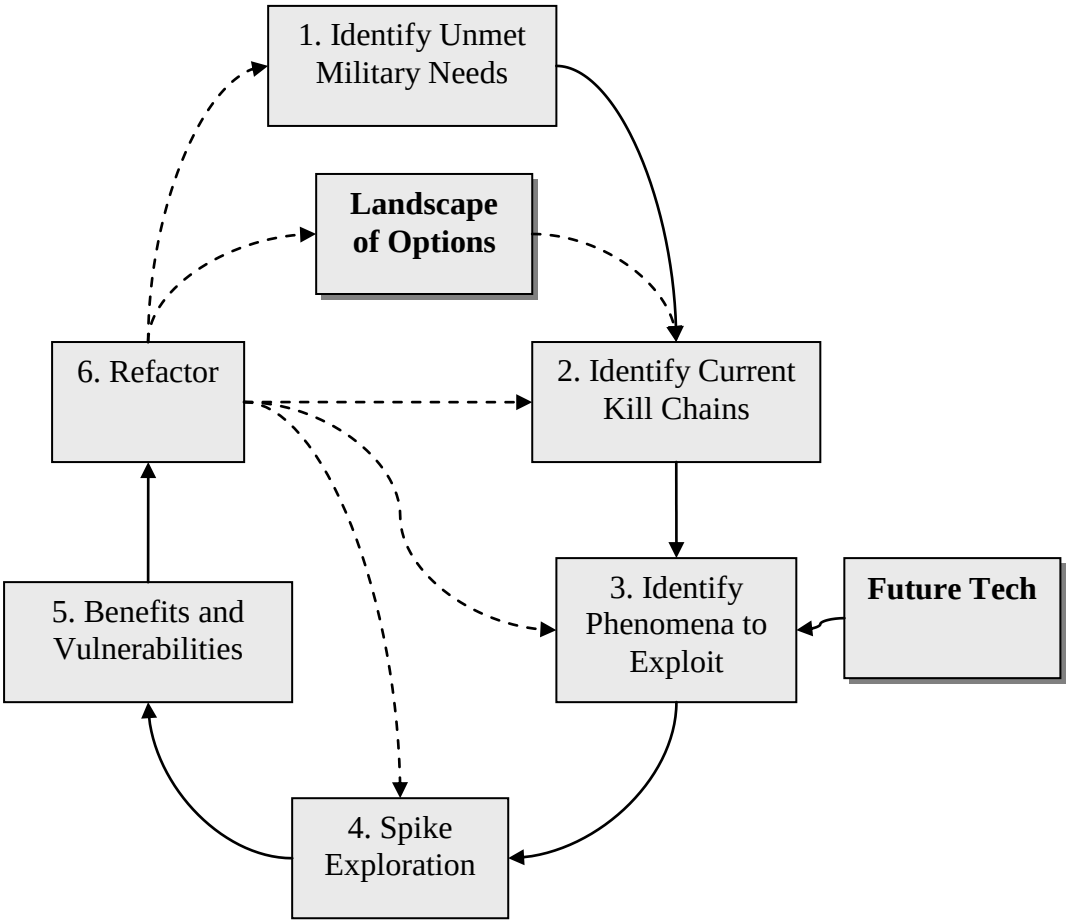

Figure 1: Activities in Concept Development

3.1 Unmet Military Needs

Identifying unmet military needs was found to be an important part of the process, even if it was not given as a starting point. This is for three reasons:

1. *War fighting advantage*. The observation was made that NCW was failing to make headway, because it was being touted as a "next big thing" to be aspired for on its own merits. The need to distinguish the "next big thing" from "unmet needs of customers" is well-understood in the technology development world, and translates directly into the defence domain in terms of finding or retaining war fighting advantages.

   The significance for NCW in the Australian context is that, in key areas including offensive air support and airborne operations, significant portions of NCW thinking were being driven by current (in 2006-07) operations in Iraq and Afghanistan. However, under extant guidance from the *Defence 2000* White Paper (Commonwealth of Australia, 2000) and subsequent *Defence*

Updates 2003 and *2005* (Department of Defence, 2003) (Department of Defence, 2005), the ADF contribution to such operations is *not* to be a driver of capability; the core capabilities are raised for Defence of Australia, with additional provision made for interoperability and integration in operations abroad. Strategically, and for the Australian Government and taxpayers as customers, the war fighting advantages to be gained from injecting NCW did not immediately follow from adopting the concepts or systems of allies.

2. *Focus and scope*. Centring the investigation on an unmet military need helped to determine what was in and out of scope, and whether options for concepts or kill chains are "good enough" to solve the problem.

   This is not meant to imply the focus of the study is static. It is accepted that the understanding of the military needs may change over the course of the study. However, there are still many avenues for exploration that distract from core of the study, delaying completion, rather than evolving and increasing the relevance of the study. When even a new avenue for exploration is identified, it is compared with the unmet military need, with three possible outcomes.

   a) The exploration is consistent with resolving the unmet military need, and the exploration is added to a list of possible explorations. (See Section 3.5).

   b) The exploration is inconsistent with resolving the unmet military need, but relates to another unmet military need. In this case a decision is made on whether the unmet military need should be re-factored to take into account the new military need (see Section 3.7). In this case, consideration of other studies being conducted, synergy between the military needs, and ability to complete the study in a timely manner are amongst the factors to be considered in reaching a decision.

   c) The exploration is inconsistent with the unmet military need, and no military need is identified. In this case, the exploration is beyond the scope of the current study.

3. *Facilitating client engagement*. The identification of the problem space helps to identify potential stakeholders with an interest in the study, and by illustrating the relevance to them it helps to draw them into the process of refining the concepts and kill chains.

   Within the Australian Department of Defence, there are adequate avenues for identifying unmet needs, or "capability deficiencies", through processes underpinned by the Needs Phase of capability development (Department of Defence, 2006). However, while the need to go beyond "like for like" replacement is well understood, it has manifestly proved difficult to implement. When introducing themselves as investigator-developers of future concepts, the authors have been universally welcomed as, "We're glad someone is doing this."

For example, in Case Study 2a the focus was initially on a capability gap in the air domain. This was useful in engaging clients in this domain. However, the sensor we were looking at operated across multiple domains, thus to discuss the options with technology experts in DSTO, and other domain experts, we needed to broaden the focus. The initial unmet military need was however, still useful in determining the scope as we encountered linkages with multi-sensor fusion (across different types of

sensor), joint fires, etc that we have identified as being beyond the scope of the initial phase of the case study.

The alignment with an unmet customer need, and the concomitant alignment with extant doctrine and practice, leads to the paradox of *apparently* not driving paradigm change, and hence not being "innovative". Specifically, one of the techniques used to socialise the work was to show how a future concept would be an implementation of extant doctrine; for instance, Case Study 2a made linkages to the doctrine of offensive support arising out of operations in Afghanistan and Iraq. The resolution of this paradox is that the doctrine was at the level of principles that admitted implementation tempos from slow time through to near real time, and command structures from conventional through to self-synchronising. When expressed in terms of the impact across the Fundamental Inputs to Capability – organisation, personnel, collective training, major systems, supplies, facilities, support, command and management (Department of Defence, 2006a) – the paradigm-shifting impact was more apparent.

3.2 Kill Chains

For a tangible implementation of a concept, it was found necessary to articulate kill *chains*: that is sequences of events where the actions of systems culminated in the successful engagement of a target. Kill chains were generated for both a *base case*, and for options in the future.

- *Base kill chains* capture the current or doctrinal implementations of capability, as a reference point for future options. . Even where a new capability or concept is being studied, knowledge of how it will interact with, or impact upon existing capabilities and concepts is likely to be important. For example, dependencies upon existing systems may impact their ability to fulfil the current capabilities, or a new concept may reduce the need for an old one.
- *Future kill chains* provide a tangible and visual link between the base kill chain and the future concepts. They can be developed for nebulous or ill-defined concepts requiring the developer to think not just about the objective, but also the implementation of the associated concept. They enable "what-if" analyses to be conducted, and trying to describe the kill chains in detail highlights areas where additional knowledge or explorations are required.

For example, in Case Study 2a the authors had identified one concept, which became 3 concepts when they first identified the steps (each of which is itself a kill chain) required if for an incremental development from the current kill chain. One of these concepts was expanded into a further 3 concepts during the kill chain development, another had 2 possible kill chains depending on the technology that was used in the implementation, and each has several implementations depending on the organisations and platforms that will fulfil each role.

These kill chains may be thought of as OV-1s in the C4ISR Architecture Framework (C4ISR Architecture Working Group, 1997), and will be described here using the same terminology as the C4ISR Architecture Framework (C4ISR AF). They are similar to OV-1's in that they focus on a subset of the platforms that are of interest. However, C4ISR AF and other process mapping tools including UML were found to be insufficient for supporting concept *creation*. To be specific, C4ISR AF had an emphasis on precision and accuracy that supported the capture of requirements for subsequent implementation in working hardware and software, but the same rigidity

interfered with the exploration of new concepts. Hence, while the kill chains presented here may resemble OV-1's as an output, they were not arrived at through C4ISR AF processes.

In the most recent studies the template for the kill chains has included:

- *A timeline*. Individual or parallel missions are shown running from the left to right of the page. Timing, , is shown at least to the level of "Pre-Mission", "In-Mission" or "Post-Mission", where a mission is defined by activity in a hostile area. Sequential missions are highlighted by different coloured threads. Earlier missions appear towards the top of the page; latter missions towards the bottom of the page. More complex interlacing of missions is not currently supported.
- *One or more operational nodes*. These could be specific platforms, organisations or individuals, more be generalised to a type of platform or generic role, as in Figure 2.
- *Information flows*. Information flows are shown by lines between nodes. Pre- and Post- Mission information flows are coloured according to the relevant mission. Broadcasts are shown by a line between two nodes, with dots indicated that intermediate points in the flow also receive the information. In the current template, all information flows are depicted in the same manner, and the possible communications mechanisms are discussed in the associated text. However, where it is known that different communications mechanisms are in use, then different line styles or colours could be used to clarify the mechanism being used for each information flow.
- In the future, additional elements that may be shown include location and a better representation of complex interlacing of missions. The challenge here is to show the range of possible interlacing without scripting the time-line in detail.

In Figure 2, which is taken from Case Study 2 (and is applicable to both studies 2a and 2b), timing is shown as "Pre-Mission", "In-Mission" or "Post-Mission", where a mission is defined by activity in a hostile area. There are two missions, one shown in light blue (which occurs earlier as it is higher up the diagram) and one in purple. The Collector is the main asset in the first mission. The analyst links the two missions, taking information from the collector, processing it, and passing it to the Commander and the User (in this case via broadcast as there is only one line between the Analyst and the other nodes), the later of which is the main node in the second mission. In this case, there are no in-mission communications.

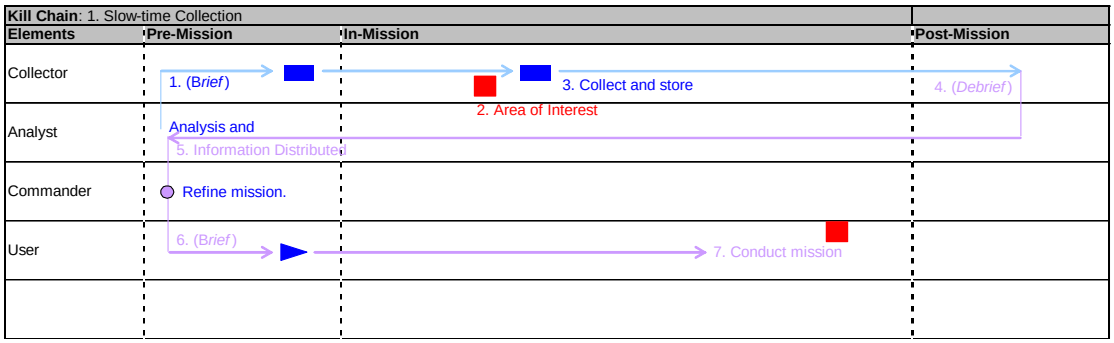

Figure 2: Case Study 2, Base Kill Chain

For the study of network-centrism, two avenues of enquiry were:

- *Pre- / Post- Mission to In-Mission*. Given that a process passed through the pre-mission and/or post-mission columns, the question was about whether and how communications would support in-mission exploitation. In Figure 2, and example would be in taking the elements from 3. Collect and store to 4. (Debrief), and disseminating to other elements directly.
- *Node-node integration*. Communication manifested as vertical lines on the diagram; for example, in Figure 2 vertical lines between Collector and Analyst, and then Analyst to User. Each vertical line needed to be studied in terms of its communications support: bearers, protocols, message sets and applications.

These two lines of enquiry tackled the "innovation" aspect of injecting NCW – instead of executing the existing base kill chain faster end to end, the chains were shortened horizontally and broadened vertically. The third line of enquiry was to add further nodes, the subject of the next section.

3.3 Phenomena to Exploit

The authors sought to identify phenomena that could be exploited or that would require a paradigm shift or discontinuous change. These could be changes in technology, the political landscape (such as military alliances between countries), threats, platforms available, resources available or the skills sets of the people. For example, a paradigm shift might be required if the same effect is to be achieved with a reduced budget, fewer people or against a greater threat. The phenomena examined in each of the case studies are summarised in Table 1.

The phenomena of interest often evolved during the course of the case study. For example, Case Study 2a: *Exploiting Remote Sensing* started off with a technology focus, and uses this as the primary representation of the landscape that captured all of the options that were developed.

Table 1: Phenomena Examined in the Case Studies

Phenomena	Case Study			
	1	2a	2b	3
Technology		Initial Focus	X	
Systems	X	X	X	
Platforms		X	X	
Information Flows	X	X	X	X
Organisational Structures		X	X	
Roles		X	X	X
Processes				
Command and Control Arrangements	X	Limited	X	X
Timeframes (cycle time, repeats)	X		X	
Products (number, resolution etc)			X	
Users			X	
Threats	X	X		
Political Alliances	X			
Budget				

3.4 Landscapes of Options

Figure 3 is a declassified version of the technology landscape that was used in Case Study 2a. The technologies are shown in blue, the main kill chains (or concepts) in yellow, and a secondary kill chain that goes beyond the scope of the initial problem (looking at sensors) is shown in grey. In the classified version, the kill chains are not linear, just as kill chain 5 and the grey kill chain are non-linear.

The key insight from the classified version of Figure 3 was in showing where the Australian Defence Force (ADF) stood, and the range of concepts that could come to realisation within the lifetimes of systems under present attention for major investment. The landscape fitted onto an A4 page, and the point in the upper left hand corner was highlighted. The point was then made that the ADF had the potential for multiple paradigm changes as represented by proceeding across the landscape.

Without these changes it would become vulnerable to the evolution in threats, but implementing each concept as the capabilities became available could result in change fatigue. Therefore the ADF needs to select those paradigms that offer the best intermediate points from a technology, operational and human resource perspective.

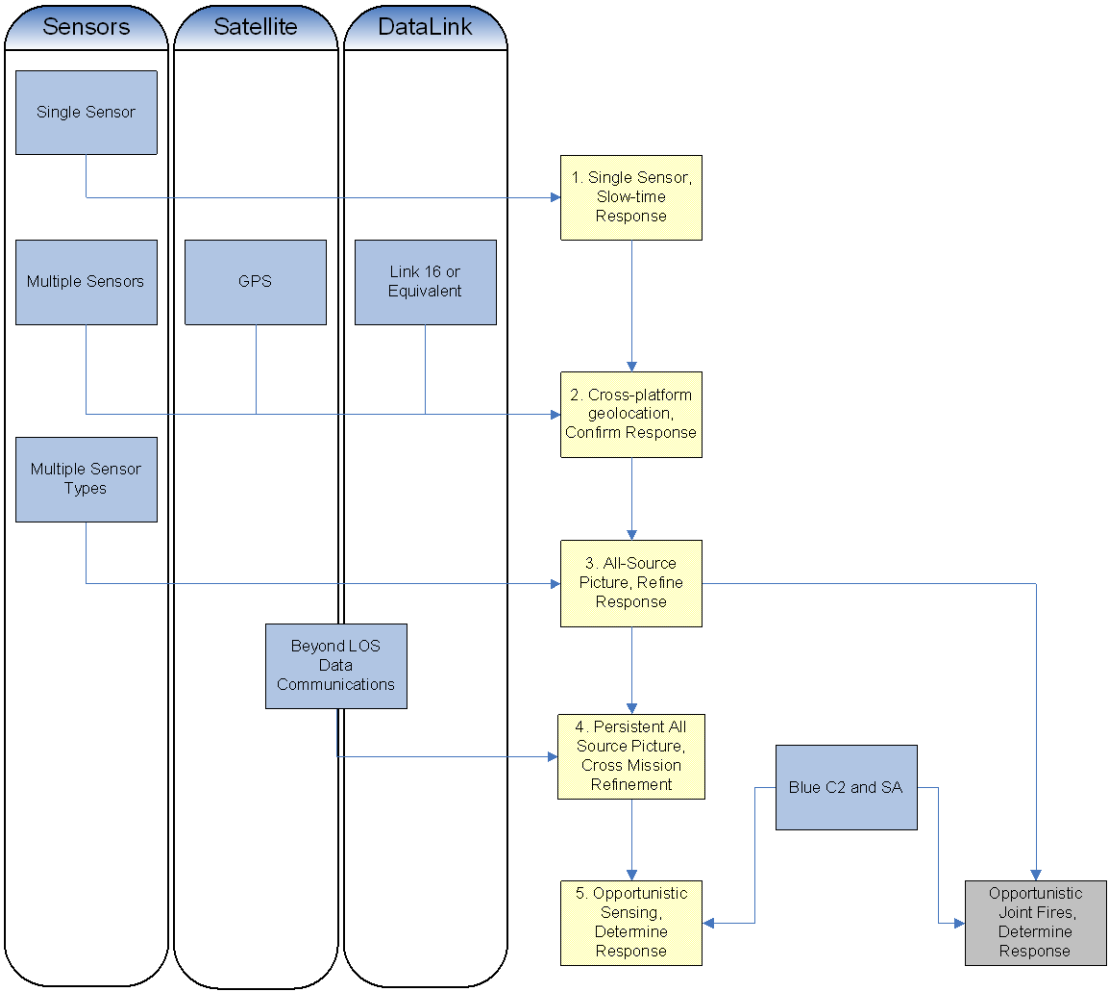

Figure 3: A sample Technology Landscape.

Figure 4 shows the landscape that was used in Case Study 1. The landscape captured the way that systems could be brought to bear against an air attack threat, including air defence missiles and fighter aircraft defences, but also including strikes on enemy bases and information or diplomatic operations (Hew, 2008). This constituted a landscape of systems, unified by an overall metric of reducing a threat, where each ring brought to bear functionally different effects. The key insight of this landscape was to show how Defence's investment needed to be integrated with policy development across the whole-of-Government.

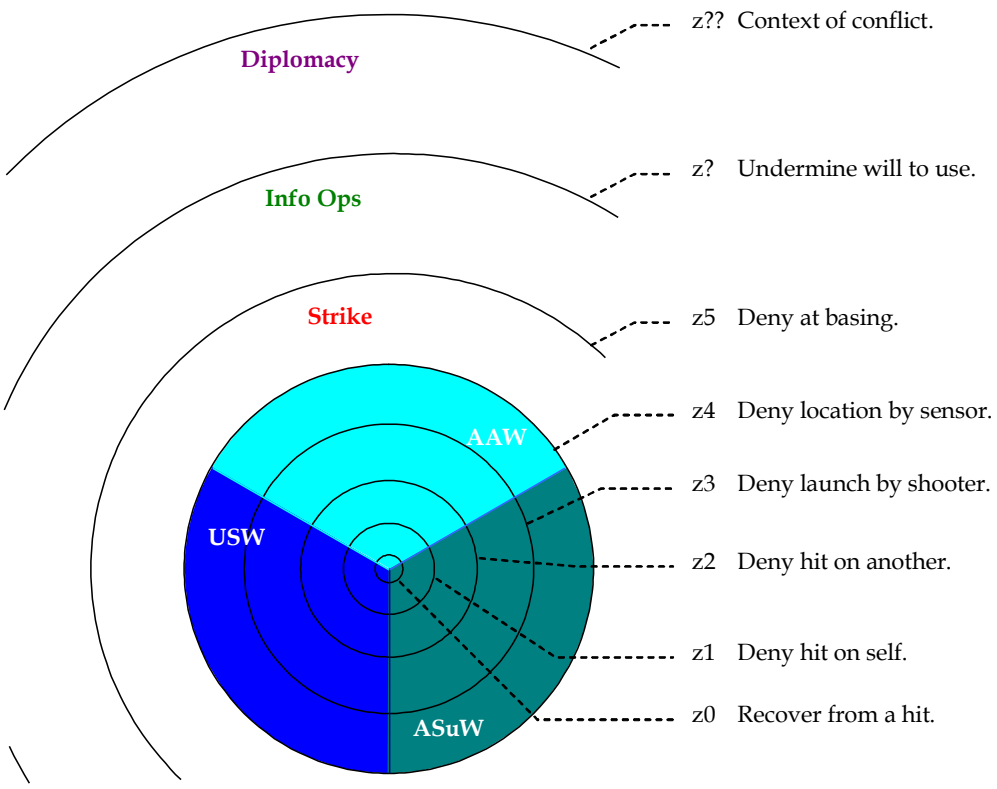

Figure 4: A sample Systems Landscape.

3.5 Spike Explorations

Spike explorations are the main mechanism that was used to evolve the understanding of the problem and options for kill chains and concepts. These involved taking either part of landscape and focusing on it – for example, examining a particular kill chain or sub-set of kill chains – or considering the whole landscape from a particular perspective. Some examples of the types of spike explorations that have been conducted, and their impact are discussed below.

- *Individual Kill Chains*. For each of the concepts in the landscape (eg Figure 3), how could the concept be implemented? What roles are needed and what platforms or organisations could fulfil those roles? What information needs to be communicated and over what systems could it be passed? Are there alternative ways of implementing the concept, and if so, what are they?

  These explorations form the basis of all other explorations. They were used to investigate the feasibility of the concepts in Case Study 2a, and the epochs in which they might be implemented. Problems encountered or opportunities identified lead to other forms of exploration.

- *Timeframes*. How long does it take for information to be passed through the kill chain? What are the implications? How long does it take for repeat cycles? For how long can these repetitions be maintained?

  For example, in Case Study 1, the time for information to get from the sensor to the shooter was critical. By focusing on the timeframes the study was able to highlight the differences between the proposed kill chains / concepts and to identify improvements to the different kill chains/concepts.

- *Cross Kill Chain Concepts*. What changes are needed to go from one kill chain to the next? If multiple changes are needed to go from one concept to the next, are there any intermediate steps? What would be the benefit of using one of the intermediate steps? Which concepts could be implemented through planned capability? If two concepts can be implemented using the planned capability, why is the intermediate capability needed?

  For example, in Case Study 2a, an additional concept was initially proposed. This was the idea of generating a situation awareness picture from the single sensor type. However, when the kill chains were detailed it was determined that the same technology could also be used for the all source picture (concept 3). Therefore, the additional concept was removed from the landscape.

- *Cross Kill Chain Systems*. What are the implications of trying to standardise on a minimal set of systems (eg communications) to support the concept? What are the implications of maximising the use of existing systems? What is the minimum set of systems that is sufficient to implement all of the concepts? How would the concepts/kill chains change if we focused on expanding the use of existing systems?

  For example, in Case Study 2a, Kill Chain 2 could be implemented quickly using different communications systems than Kill Chain 3. However, choosing to implement Kill Chain 2 in this manner would require either re-implementation of these systems or the creation of gateways between the systems to support Kill Chain 3. The alternative of implementing the new communications system to support Kill Chain 2 would delay its implementation, but would enable a more cost-effective and efficient solution to Kill Chain 3.

- *Cross Kill Chain Organisations*. What changes are required to the organisation structures, roles, responsibilities and processes across the kill chains? How feasible are they? What are the implications for training, recruitment and retention?

  For example, in Case Study 2a, Kill Chain 5, the tasking and autonomy of the sensor asset is changed from advanced tasking and autonomous operation, to near real-time tasking in response to an in-theatre off-platform commander. These considerations have been proposed for consideration in separate studies.

- *Benefits and vulnerabilities*. While the individual kill chain analysis described previously looked at the feasibility of implementing the concepts, these types of exploratory analysis are designed to stress test both the kill chains (either individually or in groups) more rigorously. They may look at both socio- and technical aspects of the kill chains including:

  - Do the technical systems, organisations and individuals really have the collective capability to meet the requirements of the kill chain?
  - What could go wrong in the kill chain? How could it be handled?
  - What level of threat can the kill chains handle?
  - What happens when the kill chain is combined with kill chains from other domains? That is, what happens when the platforms,

organisations and individuals have additional roles that they also need to perform?

- How does the kill chain compare to kill chains from other domains? (Cost-benefit comparison).

These are merely examples. A spike exploration can be conducted to explore any phenomenon of interest.

Spike explorations can also take any form. They may be based on reference to the literature, discussions with technical or operational experts, analysis of technical information about systems, operations analysis, simulations, war games, case studies, interviews, experiments, or a combination of the above.

For example, Case Study 1 used studies by domain experts to identify communication paths between the sensor and the shooter, simulation to study the results of engagements given a set of assumptions, and war games to explore and assess the assumptions and the strategic, organisational, and operator impacts of alternative kill chains.

3.6 Benefits and Vulnerabilities

This step is a prelude to the refactoring (see Section 3.7). It involves taking a step back from the details of the spike exploration to clarify what has been learnt, and make a decision on the future directions of the study.

The decisions to be made will depend on the type of spike exploration that has been conducted, and the discoveries that have been made.

Discovery	**Decision to be made**
New Concept or Kill Chain	New Spike Exploration; Refactoring
New Exploration	New Spike Exploration
New Unmet Military Need	Refactoring
New Kill Chain Representation	Refactoring
New Benefit or Vulnerability	Refactoring
New Information about one or more Systems, Platforms, Organisations, Technology (or sub-kill chain – eg timing)	Refactoring
Identification of a new system, platform, organisation or technology.	Refactoring; New Spike Exploration
No discovery	New Spike Exploration

The decision will be made based on the perceived benefits of the work, the relevance of the work, and the impact (or vulnerabilities in the study) that will arise from not doing the work.

3.7 Refactoring

Refactoring is the process of going through previously conducted work and updating it based on the information from the latest spike exploration(s). At the extreme, it

involves completely restructuring the work. However, it is more likely to involve recasting the work in a new context (due to a new unmet military need or a newly identified concept or kill chain) or updating information and implications from previous studies.

For example, in Case Study 2a the Technology Landscape was re-factored 5 times. In the first iteration, it wasn't even a Technology Landscape. It tried to bring together a variety of phenomenon that could be exploited, but did not show how this related to the kill chains. However, as the concepts and kill chains evolved, it became clear that the key distinguishing phenomenon was the degree of technological sophistication that was being employed. Later iterations were required as new concepts, kill chains, technologies of interest and stakeholder groups were identified. The currently technology landscape consists of two versions – one for military operators, and one for the research community. Other studies in the same area could have identified alternative approaches.

4 Discussion

The approach discussed in this paper has been successfully used to develop new options for concepts and their implementation as "kill chains". It is being used to facilitate the generation of ideas and options, and as yet is not a repeatable process.

In two similar studies (Case study 2a conducted by the authors and Case Study 2b conducted by a colleague) both similar and unique kill chains were developed. There are several possible sources of these differences. The first is that the studies addressed different unmet military needs. The second is that while Case Study 2a has explored a wide landscape and aimed to identify at least one feasible implementation for each point in the landscape, Case Study 2b explored a slightly smaller landscape, but examined the full range of possible implementations within that landscape. That is, while for Case Study 2a it was sufficient to know that the sensor could be networked to at least one shooter (both technically and from a C2 perspective) in Case Study 2b the range of shooter and C2 possibilities was examined. This led Case Study 2b to consider of a range of options or kill chains, which are dependent on the C2 while Case Study 2a focused on options that were primarily driven by technology changes.

In the future, refinements will be made to the process as new studies are undertaken, as the organisational and human aspects of the current studies are further explored. One question that will need to be addressed is how to capture the concepts and "kill chains" so that interactions between different concepts can be explored. To-date, the diagrams have been captured in as graphical artefacts using Microsoft products, but with no underlying database of relationships. While this was sufficient for the studies at hand, it could limit future reusability. Historical architecture tools, such as System Architect (Telelogic, 2007) or CORE could be used. However, while most of these tools provide good support for developing views and populating an underlying database, they provide limited support for querying and developing new views based on the content of the underlying database. The rapid integration of kill chains derived from exploration of different "military needs" will require both.

5 Conclusions

The authors have now completed three studies that sought a step-gain in war fighting advantage for the Australian Defence Force, through the injection of networking and

other emergent technologies. In doing so, they had to revisit their methods, departing from the rigid process capture of C4ISR AF into something more resembling the software product prototyping and refinement. A particular template was the kill chain chart, resembling "swim lane" or activity diagrams (such as those used in UML, eg Miller, 2003) but with explicit pre-mission, in-mission and post-mission columns, to trigger exploration of how kill chains could be qualitatively shortened to in-mission exploitation, and broadened across nodes. The broadening across nodes also paved the injection of emergent technology, to exploit previously-unexploited phenomena and hence add new capabilities. While the authors' tool are still in flux, the results have influenced major capability investment decisions within Australian Defence, and have seeded long-range research programmes within the Defence Science and Technology Organisation.

Acknowledgements

The authors thank the following people for review comments, the informative discussions they have held on research methodologies in general, and on processes to support the development of innovative concepts in particular: Ms Cherylne Fleming, Mr Mark Grigg, Dr John O'Neill and Dr Jeremy Manton. The authors' ideas have benefited greatly from these discussions.

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