

## Chapter 1

# About the bears and the bees: Adaptive responses to asymmetric warfare

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Conventional military forces are organised to generate large scale effects against similarly structured adversaries. Asymmetric warfare is a ‘game’ between a conventional military force and a weaker adversary that is unable to match the scale of effects of the conventional force. In asymmetric warfare, an insurgents’ strategy can be understood using a multi-scale perspective: by generating and exploiting fine scale complexity, insurgents prevent the conventional force from acting at the scale they are designed for. This paper presents a complex systems approach to the problem of asymmetric warfare, which shows how future force structures can be designed to adapt to environmental complexity at multiple scales and achieve full spectrum dominance.

### 1.1 Introduction

The cold war was a story about two giant bears, Uncle Sam and Mother Russia, armed to the teeth and locked in the dynamic stability of mutually assured destruction. The nuclear arms race saw both bears grow stronger and more dangerous. The only non-catastrophic resolution could be voluntary withdrawal by one side, which occurred when Mother Russia backed down, exhausted and weak from keeping pace with Uncle Sam. Now the undisputed power in the woods, Uncle Sam felt lost at first without the focus that a life-threatening adversary demands. Searching for animals that might one day become powerful

bears, Uncle Sam encountered many mystical animals: dragons, elephant gods and a reptilian Godzilla, although none seemed interested in confronting the dominant bear on his terms.

So Uncle Sam went into hibernation, until one September several sharp stings rudely awaked him. Enraged, the bear found the small bodies of the bees that had released their venomous barbed stingers in his flesh<sup>1</sup>. Uncle Sam tracked the honey trail to a hive in the mountains, which he smashed with his giant paws. Unsatisfied, the bear continued over the mountains and into the desert where the bear knew of another beehive, rumoured to have even nastier stings. This hive too was quickly smashed, but Uncle Sam was in for a surprise. For this species of desert bee was more aggressive and easily agitated. Every time they stung the intruder, an alarm pheromone triggered more bees to attack. The swarming enemy was small, mobile and dissolved into the desert under direct attack, which rendered the bear's keen eyesight and large muscles ineffective and impotent. Crushing individual bees could not destroy the swarm, and even when the bear had limited success, a Goliath triumph over David could do little to win the hearts and minds of the neighbouring animals. Truth be told, the locals rather thought the bear was stirring up a hornet's nest.

This story illustrates just a few of the issues associated with the transition from the cold war era to the so-called Global War on Terror. It is a problem that is relevant to every nation state in every region. Terrorism is asymmetric, enduring, ancient, unencapsulated and continually co-evolving: it is the kind of problem that has most stubbornly resisted conventional scientific reduction, the kind of problem that has helped motivate the rise of systems thinking.

Section 1.2 provides insights from complex systems theory, explaining in terms of organisation and scale why the bear is ineffective against the bees, and introduces adaptation as a possible response. The conjunction of systems engineering and complex systems (beginning to be recognised as a separate field as complex systems engineering) is developed in Section 1.3 to provide a new approach to developing capabilities for complex environments. Section 1.4 explains the attrition warfare paradigm that conventional forces are organised to fight, which is contrasted with asymmetric warfare in Section 1.5. Adaptive responses to asymmetric warfare are discussed in Section 1.6.

## 1.2 Complex systems

Two complex systems ideas are useful for understanding asymmetric warfare: multiscale variety and adaptation. The **law of multiscale variety** [4, 5] is an extension of Ashby's law of requisite variety [1]. Assume that a system has  $N$  parts that must be coordinated to respond to external contexts, and the scale of the response is given by the number of parts that participate in the coordinated response. Secondly, assume that under (complete) coordination, the variety of

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<sup>1</sup>I thank Martin Burke for suggesting this metaphor for asymmetric warfare. Swarms of bees are also discussed as a metaphor for effects-based operations in [10].

the coordinated parts equals the variety of a single part. Then, coordination increases the scale of response, but decreases its variety: there is a tradeoff between large scale behaviour and fine scale complexity<sup>2</sup>. The generalised law of multiscale variety states that at every scale the variety necessary to meet the tasks, at that scale, must be larger for the system than the task requirements [5].

**Adaptation** is a generic model for learning successful interaction strategies between a system and a complex and potentially non-stationary environment. The environment is treated as a black box, and stimulus response interactions provide feedback that modifies an internal model or representation of the environment, which affects the probability of the system taking future actions. For the case that the system is a single agent with a fixed set of available actions, the environmental feedback is a single real valued reward plus the observed state at each time step, and the internal model is an estimate of the future value of each state, this model of adaptation reduces to reinforcement learning. However, an adaptive system may also be comprised of a number of agents acting and sensing the environment in parallel, in which case the representation is distributed. The distributed representation may not be consistent or complete, but can be thought of as an ecology of cooperating and competing models, each partially representing some aspects of the environment.

The three essential functions for an adaptive mechanism are generating variety, observing feedback from interactions with the environment, and selection to reinforce some interactions and inhibit others. Without variation, the system cannot change its behaviour. Without feedback, there is no way for changes in the system to be coupled to the structure of the environment. Without preferential selection for some interactions, changes in behaviour will not be statistically different to a random walk. First order adaptation keeps sense and response options constant and adapts by changing only the probability of future actions. However, adaptation can also be applied to the adaptive mechanism itself [6]. Second order adaptation introduces three new adaptive cycles: one to improve the way variety is generated, another to adapt the way feedback is observed and thirdly an adaptive cycle for the way selection is executed. If an adaptive system contains multiple autonomous agents using second order adaptation, a third order adaptive process can use variation, feedback and selection to change the structure of interactions between agents.

### 1.3 Complex Systems Engineering

Complex Systems Engineering when taken literally is a contradiction in terms. If conventional approaches to modelling do not capture the dynamics of a complex system, we cannot expect to predict the effects of design choices on behaviour, an essential precondition for engineering. Therefore, either the systems we can

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<sup>2</sup>In this paper complexity is defined as the (log of the) number of possible configurations, and is therefore a measure of variety.

engineer will never actually be behaviourally complex (and certainly no more complex than the designer), or else we need to develop a new understanding of what it means to design and engineer a system. And since there appears to be no bound to the complexity of problems we can imagine engineering solutions to, the latter course of action seems inevitable.

In order to increase the complexity of engineering designs, the first step is to surrender the security blanket of complete understanding and control of the systems we design. We must acknowledge real limits on certainty and predictability of system behaviour, and that complete test and evaluation is not feasible [3, Thm A]. Rather than planning a design centrally, the design occurs distributed across a team with managerial independence, relying more on market forces and end user feedback than the ability of the lead systems engineer to understand and predict the behaviour of the whole system.

Each designer would be responsible for developing a functional building block for the system, capable of operating independently. The way in which different functions interface would not be pre-specified. Interfaces would be negotiated locally as the building blocks are developed, creating large numbers of possible interaction networks. Whereas traditional systems engineering takes a glueware approach to integration that tends to minimise the number of possible interaction patterns [9], harnessing self-organising mechanisms to produce global structure provides an important source of variety. Even when the components of a self-organising system are fixed, the multiple possible organisations of components provides the flexibility to respond to unexpected environments and exploit unplanned functionality.

Traditional systems engineering assumes fixed epochs, where one system is replaced by a new system that is essentially designed from scratch. However, complex problems will not have fixed solutions, so the design, develop, operate, and dispose life cycle is artificial. Rather than one-off replacement costs, complex systems engineering projects could be given a continual flow of funding that incrementally changes the system. The system is always operational, and the distinction between legacy and current systems is dissolved. Because the interaction patterns are not fixed, as new components are added the system will self-organise to include them. Some of the new components will directly compete with legacy components for links. As the new components demonstrate better performance, their interactions will be reinforced, while old components that fall into disuse can be removed. The coexistence of generations in the one system provides redundancy [2], which alleviates the need for exhaustive test and evaluation and allows greater risk-taking and innovation when designing new components.

## 1.4 Attrition warfare

Conventional military forces are organised to generate large scale effects against similarly structured adversaries. Industrial age mass production allowed nation states to re-equip and reorganise rapidly following defeats in battle that in the

Napoleonic era would have been decisive [10]. Therefore, industrial age armies had to be prepared to fight wars of attrition, where the primary aim is the physical destruction of the adversary's armed forces and its support base. Because of this, the attrition 'game' is dominated by the physical resources or mass each player can bring to bear. Each side competes to produce effects on a larger scale in order to overwhelm their opponent's defences. The Lanchester differential equations are the classical model for attrition warfare because they capture the importance of mass in achieving the physical destruction of an opponent. The Lanchester equations [8] relate the mass and effective firing rate of one side to the rate of attrition of the opponent. The solution is known as Lanchester's square law, which shows that increases in initial mass will produce quadratic improvements in battlefield superiority compared to improvements in weapon efficiency.

So how is a conventional force organised? We will consider two organisational drivers for conventional military structures. Firstly, there has been a trend throughout the history of warfare towards greater lethality at all levels of warfare in order to mass a large scale effect in the shortest possible time frame. As is expected from the multiscale law of requisite variety, this emphasises greater coordination of the activities of units at all levels. Synchronisation enables the exploitation of synergies and compensation for weaknesses of different units within combined arms teams, and at a higher level of organisation by joint warfighting. Centralised control, detailed planning and collective training exercises are the dominant mechanisms for producing synchronised effects. A continual focus on synchronisation to produce large scale effects has encouraged specialisation. Specialisation can increase efficiency by avoiding redundancy, but it also locks in dependencies between units, reducing the ability of units to operate in isolation at finer scales. In order to focus effects, conventional forces are organised to be spatially oriented towards the forward edge of the battle area, with most protection for the front-line manoeuvre units, less protection for stand-off indirect fire units and little protection for the rear logistics supply chain.

Secondly, with increasing lethality comes increasing responsibility and the potential for the misuse of force to adversely affect the strategic goals of conflict. This has reinforced the use of centralised control and codified procedures to limit flexibility and prevent strategically detrimental application of force. Highly centralised hierarchical control reliably amplifies the scale at which the commander can control battlespace effects, at the expense of the fine scale variety (complexity) that the conventional force can cope with.

## 1.5 Asymmetric warfare

In contrast to attrition warfare, asymmetric warfare is a 'game' between a conventional military force and a weaker adversary that is unable to match the scale of effects of the conventional force. To compensate, the weaker adversary must believe their will to accept the costs of conflict is greater than their opponent.

What began as Operation Iraqi Freedom, and is now referred to by the Pentagon as the Long War, is a paradigmatic example. The US-led Multinational force is opposed by an Iraqi insurgency composed of approximately 14 guerilla organisations, each with distinct aims and relatively independent operations. Although the insurgents have limited material means, their religious and ideological motivations provide strong will. A history of aversion to casualties in democracies during conflicts, especially when the conflict is peripheral to the nation's core interests, provides a basis for the insurgents' belief that the Multinational force's strategic will can be weakened if domestic support for a continued presence in Iraq is sufficiently eroded. At the tactical level, suicide bombings represent an asymmetry in will, where suicide bombers have sufficient will to utilise methods outside those available to the Multinational force.

For insurgents to exploit their asymmetries, they must also negate the asymmetries that favour the conventional force. In particular, they must avoid direct, large scale confrontation against the better equipped, trained and synchronised conventional force. This can be understood using a multi-scale perspective: by generating and exploiting fine scale complexity, insurgents prevent the conventional force from acting at the scale they are organised for: large scale but limited complexity environments.

By dispersing into largely independent cells, insurgents can limit the amount of damage any single attack from the conventional force can inflict. This significantly reduces the threat of retaliation from acting as a deterrent, since the insurgents have negligible physical resources exposed to retaliatory attack [10]. Insurgents that do not wear uniforms and blend into a civilian population cannot be readily identified or targeted until they attack, in a situation of their choice. There is no longer a forward edge of the battle line, meaning softer support units are vulnerable. The number of possible locations, times and direction of attack increases significantly compared to attrition warfare, increasing fine scale complexity. The heightened potential for collateral damage from mixing with civilian populations dramatically increases the task complexity for a conventional force that must minimise the deaths of innocent civilians for any hope of strategic victory.

By moving into complex terrain, such as urban or high density vegetation, the Multinational force's most expensive sensors (such as satellites and radar) designed to detect large scale movements are ineffective due to the fine scale of physical activity, which provides a very low signal to noise ratio. In this situation, insurgents control the tempo and intensity of the conflict, which enables them to exploit niches in the fuzzy spaces near artificial boundaries, such as the traditional conceptual dichotomies of war/peace, combatant/non-combatant, state/non-state actors, and tactical/strategic operations, adding further to complexity. The ability to mass synchronised battlespace effects is of little use in such a complex situation.

## 1.6 Adaptive responses to asymmetric warfare

Clearly the conventional force requires a different organisation to respond to asymmetric powers, while still maintaining the ability to generate large scale effects when required. The force must be able to generate sufficient variety in effects at every scale, from peace-keeping and peace enforcement crises to high intensity warfighting, to achieve full spectrum dominance. Because the biggest capability gap is currently in asymmetric warfare, we will focus on this context.

Currently within the Australian Army, units form Platoons or Troops, each with a specialist function, such as to detect, respond or sustain. The Platoons in a Battlegroup can then be combined to form Company level combat teams, and integration at lower levels is uncommon. In contrast, the Australian Complex Warfighting concept [7] outlines a new type of organisation to cope with increased complexity. Smaller, austere, semi-autonomous teams with modular organisation are envisaged. These teams use swarming tactics and devolved situation awareness to operate as self-reliant teams that aggregate to achieve larger scale effects through local coordination rather than central control. Teams would not be as specialised as current units, since each team must be largely self-reliant for logistics, sensing, decision-making and responding to threats. The difference between a logistics and reconnaissance team for complex warfighting would be a matter of emphasis, since both would have a base capability for mobility, survivability, detection and response. Complex warfighting tasks such as asymmetric warfare require a shift in conventional force structure towards special forces structures.

Each of these changes are consistent with complex systems insights. However, the new organisation presents additional challenges. Whereas a centralised system promotes standardisation of equipment and process, semi-autonomous teams will deliberately promote variety. As well as reflecting differences in local context, the variety will exist because some teams will discover successful strategies that are unknown to other teams. Therefore, it is necessary to promote the spread of successful strategies between autonomous teams to improve overall force effectiveness. However, if successful variations are adopted too readily, the reduction in variation between teams will diminish the force's ability to adapt. There exists a tradeoff between being adapted (specialised) to the current environment, and adaptability for future contexts.

Another challenge associated with semi-autonomous teams is ensuring that the goals of the autonomous teams are aligned with force level goals. Abu Ghraib is an example where the pursuit of local goals (extracting intelligence) produced extremely damaging strategic effects. The impact of socio-cultural issues on strategic success is clear in this example. The interplay between increasingly ubiquitous mass media and populations that value surprise in news (which Shannon's theory accounts for) act to reinforce the perception of anomalies, and can also reinforce the public response. For armed forces, the more independent teams become, the more likely at least one team will develop a culture that reinforces strategically counterproductive behaviour. The role of higher level headquarters

that manage semi-autonomous teams will be to clearly communicate and then police the boundaries of acceptable behaviour, within which autonomous teams have freedom to innovate.

This kind of force structure places very different demands on the capability development process. Whereas a conventional force demands standardisation so that effects can be synchronised and the output of units is predictable, complex warfighting teams will be heterogeneous and have varied demands for materiel. An industrial age approach to capability development tailored to large scale production of standardised materiel is unsuited to meeting the fine scale but complex demands of the new force structure. In contrast, the complex systems engineering model introduced in Section 1.3 enables a much more responsive development process. Individual autonomous teams could test new ways to sense and respond to asymmetric threats, enabling them to adapt at the secondary level. From the capability development perspective, semi-autonomous teams provide an ideal entry point and realistic test bed for new systems, and allow the coexistence of legacy and experimental systems discussed in Section 1.3. If the system provides a significant benefit, demand for it will quickly spread through the network of teams. If a new system has a negative effect on one team's performance, at least it will have a negligible effect on overall force performance due to the autonomy of the teams.

In order to be effective, the adaptive response must occur at all levels. At the strategic level, the use of complex warfighting teams to deny targeting success is only one available strategy in a space that includes economic, political and information operations. In this space, the effects of taking different sets of actions is typically far less certain and first, second and third order adaptive cycles can play a crucial role in identifying and exploiting useful sets of actions.

## 1.7 Conclusion

Asymmetric warfare presents a challenge of increased fine scale complexity. Current force structures are monolithic bears designed for large scale effects, and must be reorganised by devolving autonomy and increasing independence to provide sufficient fine scale variety. Once variety is available, the best way to cope with complexity is using adaptation, which can improve system performance over time and track changes in the environment. Complex systems theory has the potential to improve the way military capability is acquired, organised and managed, enabling adaptive responses to asymmetric warfare.

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