

A WOVEN WEB OF GUESSES, CANTO ONE:

Network Centric Warfare and the Myth of the New Economy

Track: Information Age Transformation

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Abstract

This is the first in a series of three inter-related papers, in which we describe the results of our critical inquiries into the NCW thesis, and propose an alternative conception of information age warfare. Our larger view is that the principal failure of the NCW thesis, and conversely the more robust response to the phenomena it seeks unsuccessfully to address is first and foremost epistemological in nature. However, in this first paper we focus our attention on a more immediate and accessible challenge to the NCW thesis, which arises from its status as a problematic argument by analogy from a discredited body of ideas in economics and business theory called New Economy theory. We find that especially as regards its interpretation of the implications of Metcalfe's Law, the NCW literature has misstated its case and overlooked several important, and often adverse, insights. We provide a restatement of the analogy, the lessons of which broadly contradict the problematic lessons in the popular NCW literature. The irony of the business analogy is that far from supporting the NCW thesis and its transformation programme, it appears to be a stern warning against it.

**But as for certain truth, no man has known it
Nor will he know it; neither of the gods,
Nor yet of all the things of which I speak.
And if by chance he were to utter
The final truth, he would himself not know it:
For all is but a woven web of guesses.**

- Xenophanes

Introduction

There is a broad consensus within the military profession that continuing progress in the domain of information technology is fundamentally changing the conditions of warfare and laying the basis for a sweeping beneficial transformation of military forces. Amongst

proponents of this view, the theory of Network Centric Warfare (NCW) has emerged as the leading conceptual framework. It is hard to overstate the influence and sway of this extraordinary new theory of warfare. It has received popular support at the highest levels of the Western defence bureaucracies. It enjoys a large international following. It has spawned an impressive body of elaborating literature and a wide and diverse array of supporting research. Especially amongst the ranks of serving military officers, thoroughgoing public criticism appears to be muted, or absent altogether. But its impressive stature notwithstanding, we submit that there are grounds for grave concern regarding the NCW thesis, and that before it works its way fully into military thought and doctrine it must successfully withstand some important challenges.

Our larger view is that the NCW thesis suffers from two potentially terminal afflictions. The first and most important originates in its heavy reliance on conventional military attitudes in the domains of epistemology and methodology. In short, we believe that the NCW thesis is animated by a flawed theory of knowledge and knowledge development, with profound adverse consequences for the thesis as a whole. But we will set these objections aside for later papers and focus here on a more immediate and accessible concern. In large measure, the NCW thesis is a freely acknowledged argument by analogy from a worldview that dominated American business culture in the 1990s. Often called *New Economy* theory, we submit that this worldview exerts all the force of a premise over the NCW thesis, providing much of its impetus and substance notwithstanding that it has receded into the background in the more recent literature. Unfortunately for the NCW thesis, New Economy theory proved to be a bubble of inflated expectations that burst with the sobering force of an 80 percent decline in the NASDAQ 100. It now stands in wide discredit and no longer has a supporting constituency in business theory and economics. With the admitted benefit of hindsight, it thus seems clearly to have been an unfortunate choice for military analogy.

We will begin this paper by describing New Economy theory and by showing how the NCW thesis is a variation on its three dominant themes: Moore's Law, Metcalfe's Law and the Internet. Then we will turn the business analogy against itself: we will accept its premise that economic concepts are a rich potential source of insight for Information Age warfare, but we will challenge as seriously problematic the lessons that its spokesmen have drawn from the exercise. In sharp contrast to the enthusiastic vision that pervades the NCW literature, we will find that there is much more to the business analogy than its proponents have dreamt of in their philosophy and that much of it is a cautionary tale. Note, however, that this paper is but the first in a series of three. In the second paper we will move on to explore the problematic epistemological and methodological aspects of the NCW thesis, and in our final paper we will extend this argument and propose and explore the consequences of an alternative methodological basis for military theory in the information age.

The NCW Business Analogy

The heady days of commerce in the 1990s should still be fresh in the memory of most readers. The decade was one of almost unbroken economic growth and stock market

gains, particularly in North America, fuelled by the happy correspondence of a variety of positive developments. But in the view of many commentators, the primary impetus for this affluence lay in the perceived economic consequences of rapid technological progress. Indeed, as the decade advanced popular consensus began to coalesce around an extraordinary hypothesis: due largely to technological progress, we were not merely witnessing an extraordinary economic boom, but a fundamental economic and commercial transformation. They called it the New Economy.

For New Economy theory, the semiconductor and the Internet were to be the engines of this transformation, thanks to the synergistic correspondence of three accelerating trends, all of which will eventually come to play an important role in the NCW thesis. The first such trend was Moore's Law, the enormously successful prediction that semiconductors would double in capacity and halve in price every 18 months. The second trend was the well-known phenomena of explosive growth in the capacity and utilization of the Internet. The third trend was Metcalfe's Law and was, arguable, the less well known but by far most important of the New Economy's triumvirate. It will consequently receive special attention as this paper proceeds, but for now we will describe it in the concise terms that typified its popular conception during the heyday of New Economy theory. In brief, Metcalfe's Law asserts that the value of a network increases in proportion to the square of the number of users of the network¹.

From the point of view of New Economy commentators, these three economic phenomena combined to form an irresistible synergy. Thanks to Moore's Law the semiconductor was shrinking in size and cost by leaps and bounds. In turn this drove a seemingly insatiable wave of new economic demand, as the semiconductor worked its way down from the mainframe computer to the toaster oven, creating a tide of undreamt of new products to buy and sell in the process. Moreover, it seemed an impressive source of unending productive efficiency as it enabled the continuing replacement of inefficient labour by pervasive automation. Thanks to the Internet, the world possessed a whole new medium of exchange, one that among other things broke down the traditional boundaries of the firm, allowing real time collaboration irrespective of geography and offering the prospect of a more efficient alternative to the tradition business structure. But, as we said above, it was Metcalfe's Law that really iced the cake. One of the almost inescapable consequences of traditional economic competition is the phenomenon of diminishing returns. As successful companies open up new markets, they typically enjoy a period of high returns. But barring some barrier to entry, these returns quickly attract competition with the result that margins ultimately diminish. By positing that the value of a network *increases* with the square of the number of users of that network, Metcalfe's Law held out the prospect of a reversal of this margin-sucking trend in economics, at least for the increasingly important information technology sector of the new economy. Amongst the

¹ The story of Metcalfe's Law starts with a packet radio system called Aloha Net, which could only use 17% of its capacity because of collision and other difficulties. Robert Metcalfe, then a PhD candidate searching for ideas for a thesis, utilized Queuing theory to bring such networks towards 90% utilization. The result was the invention of the Ethernet. Against this backdrop, Metcalfe noted that the number of inter-connections in a network containing n nodes is $\frac{1}{2}n(n-1)$. If each inter-connection has the same value, then the cumulative value of the network as a whole is dominated by the value of n^2 , ignoring the diminishing value of the other terms.

lunatic fringe of New Economy exuberance, people began to suggest that because of all of this we were even about to witness the marked amelioration, if not the final end of the traditional boom and bust cycle of the market economy.

Given the importance of Metcalfe's Law for New Economy theory and ultimately for the NCW thesis, some additional elaboration is warranted. While associated with communications networks, it is applicable to other standards-based systems². From the perspective of New Economy theory, for example, Metcalfe's Law is the economic force that enabled cassette to beat eight-track, VHS to beat Beta, and the DOS operating system to beat the Macintosh operating system. To cut the story short, Metcalfe's Law dictates that when given a choice between two standards, the rational consumer will purchase the standard that is in the widest use. In the end, cassette, VHS and DOS won their respective battles because they hit critical mass in terms of the number of users before their competition did and increased in value relative to their alternatives at Metcalfe's insurmountable and irreversible accelerating rate from that point on. Note that to the owner and producer of the standard in question, Metcalfe's Law was a thing of great beauty, for it offered the prospect of a quick and permanent entry into the promised land of monopoly status: provided, of course, that you could get your standard to critical mass before your competitors did.

It should be obvious from the foregoing why Metcalfe's Law became such a core New Economy insight, apart from its asserted influence over the market cycle. On one hand it describes a unique value-creating logic applicable to standards-based goods and on the other hand the very stuff of the New Economy – all of the impressive new hardware, software and operating systems – was precisely that: *standards-based goods*. Bill Gates had not become a multi-billionaire overnight because of the innate superiority of his 'quick and dirty operating system'. To the contrary, he had gained his unprecedented wealth by the grace of Metcalfe's Law: he grabbed DOS quickly off the shelf and gave it away for a song to the leading hardware maker, it reached critical mass in terms of the number of users before the competition did and then extended its lead at Metcalfe's unbeatable rate, leaving its opponents in the dust, and Microsoft free to lever its dominant position into unprecedented wealth. Or at least this is how New Economy theory saw it.

Metcalfe's Law was thus the key strategic insight of late 20th Century commerce and defined the emergent business and investment culture. Over and over again, a succession of high tech companies applied the same strategy: move fast, get your standard out early, give it away for free if necessary, hit critical mass first, bill your customers big time when Metcalfe's logic delivers a dominant position, build yourself a mansion in Seattle. And note how Moore's Law, with its rapid succession of significant leaps forward, and the Internet with its accelerating subscription levels, played right into Metcalfe's hands. There is no better way to leverage Metcalfe's Law into additional profits than an 18-month upgrade cycle, delivered across a lightening fast, dirt-cheap cybernetic trade route. This is why things were speeding up in the so-called New Economy, and this is why

² These are direct and indirect network effects respectively, and there are differences between them. But for our purposes we believe that these differences can largely be ignored.

wealth was being generated and moved around so rapidly: business had become a race to critical mass, winner take all.

Early NCW proponents such as VAdm (ret'd) Arthur Cebrowski and Dr David S. Alberts and his associates of the US DoD Command and Control Research Program were clearly struck by the military implications of New Economy theory and ultimately embraced its insights. As Cebrowski put it, in an article published in 1998 with John J. Gartska, "The organizing principle of network-centric warfare has its antecedent in the dynamics of growth and competition that have emerged in the modern economy."³ From that point on the paper is a sustained exploration of the business analogy, replete with specific mention of Metcalfe's Law and allusions to other New Economy tenets and their alleged military implications. Nor has his reliance on New Economy theory diminished. As recently as December 2002, at a conference held in Anaheim, Cebrowski was still using Metcalfe's Law as a key NCW concept⁴. Likewise Alberts *et al* made the NCW business analogy the primary focus of the widely read and influential book *Network Centric Warfare: Developing and Leveraging Information Superiority*⁵. The book starts with a lengthy and enthusiastic discussion of the purportedly revolutionary and permanent changes occurring in the domain of business at the time, with digressions into the supposed new logic of competition, new sources of wealth creation and new breath-taking pace that were part and parcel of the New Economy's world view. Moore's Law, Metcalfe's Law and the Internet loom large from the outset, and each is the subject of special attention in its appendices. There are several case studies purporting to illustrate examples of the so-called network-centric enterprises that allegedly defined the new economy and provide a rich source of lessons to be learned and applied in a military context. And on and on it goes. While more recent literature from Alberts *et al* does not repeat the business analogy, it has likewise never been retracted and the text is still widely distributed at no cost. Moreover, unless we consider the ultimate goal of military theory to be the generation of robust jargon, applicable in all conceivable worlds, it is difficult to see how the business analogy can be extracted from the NCW thesis without doing serious damage. New Economy theory is not merely a convenient basis for illustration in all of this: it exerts the force of a premise over the NCW thesis, providing, as we will see, much of its impetus and key elements of its substance. The two ideas are kin: they will stand or fall together.

So, do they stand, or do they fall?

The Pesky Little Problems of the Business Analogy

We will begin by pointing out that it would be possible to criticize the NCW business analogy outright, on the grounds that commerce and warfare are not sufficiently

³ Vice Admiral Arthur K Cebrowski and John J. Gartska, "Network-Centric Warfare: Its Origins and Future", Naval Institute Proceedings, January 1998, p 29.

⁴ In the presentation Cebrowski makes two references of particular relevance to the following discussion. He claims that n^2 defines the power of the network, and n defines the robustness of the network. Both are clear allusions to Metcalfe's Law..

⁵ Alberts, D.S., Gartska, J.J., Stein, F.P., "Network Centric Warfare: Developing and Leveraging Information Superiority", 2nd ed., *CCRP Publication Series*, 2000.

analogous to allow for reliable inferences using this often-abused technique. For example, economics is typically carried out within the context of some deliberate posture or other involving the “rationality principle”; or in other words, the assumption that the economy consists of many relatively well-informed and free participants working to maximize their own utility. It would be difficult to make this claim of military bureaucracies and of soldiers in battle, so to transfer the insights of economics into the domain of military theory requires considerable care at the least. Nonetheless, we will set this objection aside, except where it becomes particularly relevant, and grant to NCW proponents that there can be considerable benefit in an argument by analogy from business theory. Our real concern is not with the validity of the analogy, but with the conclusions drawn. We believe that compelling grounds exist that demand a fundamental restatement of the analogy in ways that make it incompatible with, and even contrary to the essence of the NCW thesis. We explore this restatement hereunder.

The First Problem: The Confusion Over Value

The first problem of the NCW business analogy involves the straightforward and damaging mischaracterization of the very essence of Metcalfe’s Law in the NCW literature. As we will see, this serious error results in the mistaken impression that Metcalfe’s impressive polynomial acceleration defines the benefit that will accrue from battlefield networking in particular instances or as a whole. In other word’s NCW proponents use it as a component of an informal business case to justify the investment in pervasive military networking and in the broader institutional reforms that they believe to logically follow. Metcalfe’s Law can serve no such purpose, and was never intended to.

Let us start with the stock definition of Metcalfe’s Law, setting aside important qualifications for later that are irrelevant for present purposes:

“The value of a network increases with the square of the number of users of the network.”

We submit that this definition has two potential sources of confusion. The first potential source of confusion is in regard to the word “value”, which has a specific meaning in economics, but which has arguably vague connotations in public discourse. For Metcalfe’s Law, as for elsewhere in economics, the word “value” interchanges with “utility”: a word that we suggest to be far less subject to misinterpretation. The second potential source of confusion is this: what is it, precisely, that Metcalfe’s Law asserts to be increasing in value or utility with the square of the number of users? Economic theory tells us that the answer is this: **Metcalfe’s Law applies to the goods and/or services necessary to participate on the network.** Note that there is not a word in here concerning the value of the transactions that are enabled by the network. The importance of this distinction will become clear when we turn our attention to the abuse of Metcalfe’s Law in the NCW literature immediately hereunder, but for now let us restate the law more clearly based on the foregoing discussion:

The utility of the goods and/or services necessary to participate on a network will increase with the square of the number of users of those goods and/or services.

When viewed this way, the potential confusion created by the more popular definition of Metcalfe's Law is, we submit, greatly reduced.

But now let us look at the characterization of Metcalfe's Law in the NCW literature. Let us start with a passage that is due to Cebrowski and Gartska:

Network-centric computing is governed by Metcalfe's Law, which asserts that the "power" of a network is proportional to the square of the number of nodes in the network. The "power" or "payoff" of network-centric computing comes from information-intensive interactions between very large numbers of heterogeneous computational nodes on the network.⁶

There are certain obvious rhetorical advantages to the authors' generous replacement of "value" or "utility" with the charged word "power", but this is not the questionable liberty that is most concerning in this passage. The more important misapplication of Metcalfe's Law is the subtle replacement of a noun with a verb; namely, of "computers" with "computing". As we discussed earlier, Metcalfe's Law applies to the goods and/or services necessary to participate on the network. In the NCW literature, however, Metcalfe's Law is suddenly applied to the transactions that are enabled by or carried out on the network. To put it differently, and in the terms of the passage cited above, while Metcalfe's Law may accurately be asserted to apply to networked *computers*, Cebrowski and Gartska mistakenly apply it to networked *computing*. So, Cebrowski and Gartska have redefine Metcalfe's Law something like this:

The power of transactions carried out on a network increases with the square of the number of users of the network.

This is not only a straightforward mischaracterization of Metcalfe's Law, but also a highly problematic assertion, to say the least. And if some contrary argument is needed, then here is one to consider. There is no network with more nodes than the international telephone system, so n^2 in this case would be extremely high indeed. But does this large number describe the value, let alone the "power" of individual conversations carried out on the telephone network? Hardly, for what is the power of dialling a wrong number? The utility of the network lies in the importance to its users of the conversations it facilitates, and surely dialling wrong number does not normally result in a conversation of particularly high utility to either participant. Metcalfe's Law simply does not apply to the transactions carried out on the network.

Note that the consequences of this mischaracterization of Metcalfe's Law are profound. In order to show why this is so, let us consider another example, this time from *Network Centric Warfare: Developing and Leveraging Information Superiority*, by Alberts *et al.* In a section entitled "The Power of NCW" the authors describe the alleged impact of networking on a hypothetical case involving two shooters operating in relatively close proximity. The diagram at figure 1 is reproduced, overleaf, from the passage in

⁶ Cebrowski and Gartska, *Network-Centric Warfare : Its Origins and Future*, op cit, p 35.

question⁷. Case (a) represents two non-networked, *platform-centric* shooters, with their limited engagement ranges. Case (b) represents “a geometric argument for the value-added combat power associated with network-centric operation”⁸. The geometric argument attempts to depict a purportedly significant increase in the effective engagement envelope due to a purported increase in network-enabled shared awareness and improved quality of information. In the course of their discussion, the authors make the following claim:

The potential increase in total combat power associated with a network-centric operation is represented by the increased area of the effective engagement envelope. **This simple example illustrates the application of Metcalfe’s Law to military operations.** [emphasis added]⁹

Clearly the implication here is that the value of network enabled transactions, in this case the transactions between the two shooters, is somehow related to Metcalfe’s Law, or n^2 .

Imagine the prospects if this were so, for if Metcalfe’s nonlinear curve indeed applied to network enabled battlefield transactions, then we would have a corresponding nonlinear increase in the engagement envelope with each new shooter. Imagine the size ‘combat power’ in Alberts’

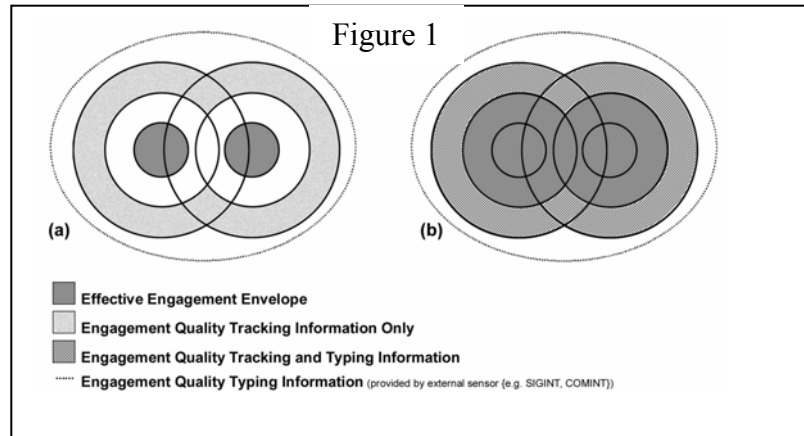


illustration if three, or thirty, or three hundred shooters or more were network-enabled. We suggest that the association between network enabled transactions and Metcalfe’s Law serves the purpose of generating excitement for the benefits of ubiquitous networking. But we also suggest that the implied gains would not survive empirical testing. More significantly we assert that whatever the outcome of any such test the question is moot: Metcalfe’s Law was simply never intended to, and does not adequately describe network-enabled transactions.

To their credit, Alberts *et al* go on to admit that the association between Metcalfe’s Law and increased combat power is not straightforward, and that additional analysis and study is required in order to realize the full potential of network effects¹⁰. Elsewhere in the

⁷ Alberts *et al* *Network Centric Warfare: Developing and Leveraging Information Superiority*. op cit, p.102. Figure reproduced by permission.

⁸ Ibid, p 103.

⁹ Ibid, p 103.

¹⁰ In fact, Alberts *et al* state, at page 252, that there are likely to be clusters of valuable interactions: a qualification that may seem to undercut our criticism here. But note two implications of this qualification. First, this contradicts an assumption that must be made in order for Metcalfe’s equation to be valid; namely that all of the nodes will be of equal value. In effect, as we will discuss later, this qualification by Alberts

text¹¹ they introduce the notion of ‘second order’ considerations such as user value functions to more fully refine the relationship between Metcalfe’s Law and value creation. But these qualifications fail to compensate for the misinterpretation of Metcalfe’s Law. Metcalfe’s Law is accurately asserted to pertain to the network and to the value of the goods and services necessary to participate on that network. It tells us that if we wish to watch videotapes we should buy a VCR-compatible machine, eschewing the far less populated Beta-based alternatives. It tells us nothing about the value of watching the movies on particular videotapes. Metcalfe’s Law is a crucial element in the attempt by NCW proponents to justify their ambitious programme. But it is only through the straightforward mischaracterization of Metcalfe’s Law that this impetus can be attained. As we said at the outset of this section, to the extent that Metcalfe’s Law is used to justify the NCW thesis, the NCW thesis remains unjustified.

Before we close this discussion we wish to clarify our own position on the value of military networking. We have no doubt that networking offers the possibility of increased battlefield performance. Indeed, we even acknowledge the possibility that, to the extent we may express it in these terms, some network-enabled transactions may improve combat power in specific instances out of all proportion to Metcalfe’s Law. But it is equally obvious that we will need something better than the broad brush of a misunderstood and improperly applied economic concept to justify large-scale investments in ubiquitous networking and large-scale network-driven military transformation. A few pointed questions may offer a better place to start. To what extent does networking *actually* improve battlefield performance? Can networking have adverse implications for performance in some circumstances? If so, how can these be managed? Who benefits, and how? Where and to what extent, specifically, are the investment and the disruption and risk of collateral change warranted by the potential gains? These and a good many other fruitful questions will not be satisfied by a misapplication of Metcalfe’s Law. Among other things we may be surprised to learn that networks have compelling limits and that they are not exclusively beneficial.

The Second Problem: A Network is a Policy Trap

The second important flaw in the NCW business analogy has the potential to create international controversy if not properly introduced. Thus we will start this discussion with an important qualification: the following discussion is in no way intended as a criticism of US intentions. Indeed, it is intended constructively and is a cautionary tale for the international community that it would be imprudent even for the US to ignore.

In the article by Cebrowski and Gartska to which we have been referring, we find frequent references to the phrases “increasing returns” and “lock-out” or “lock-in”¹².

et al is a denial of Metcalfe’s Law itself, and is merely another way of arguing our point, here. Secondly the admission that there will be clusters of valuable interactions raises an interesting question that contradicts the goal of pervasive battlefield network and seamless connectivity: Why don’t we just identify and connect the high-value nodes, and spare the expense and disruption of connecting the low-value nodes? This would be the rational, hardnosed business approach and we are, after, engaged in a business analogy.

¹¹ See *ibid*, appendix A for this discussion.

¹² Cebrowski and Gartska, “Network-Centric Warfare: Its Origins and Future”, *op cit*.

Insofar as the latter two are concerned, we typically find them used in the following context: *locking in victory* or *locking out the enemy*. In other words, these phenomena are held to be important, beneficial characteristics of networks and of the NCW thesis. While the inter-relationship is often only alluded to, these phrases and the concepts to which they refer once again find their origins in New Economy theory and in Metcalfe's Law. But once again they have been misapplied. For in the sense that New Economy theory and Metcalfe's Law actually imply these phenomena, they are not threats to our enemy, **but to our friends**. Networks do not "lock out" the enemy: they "lock out" other friendly networks. Networks do not "lock-in" victory: they "lock-in" their users¹³. For the military services of the world who are contemplating the consequences of hooking up to the central authority's standardized network, and to the national forces of the world who are contemplating the consequences of hooking up to an alliance or ally-owned and controlled network, this is a clarification of the NCW thesis and of network effects that is quite worth some serious contemplation. A network-centric interoperability programme has a sinister aspect.

Let's return to the body of economic ideas that underscore the NCW thesis. As characterized and understood in New Economy theory, networks in the sense of Metcalfe's Law belong to a particular class of economic phenomenon known as a *market externality*: loosely defined as the set of economic circumstances that upset efficient pricing in a market economy and which may allow businesses to impose a "deadweight loss" on society in the form of higher prices than would otherwise be sustainable. Metcalfe's Law thus hangs out with a dubious crowd, for other examples of market externalities include, monopoly conditions, pollution, crime and imperfect information. But note also that market externalities are not necessarily bad: a case can be made in some instances that a market externality is the lesser of social evils and public utilities are arguable in this category. Nonetheless, because of the phenomenon of deadweight loss and its potentially adverse consequences, market externalities typically receive special attention from policy makers in liberal economies. They require the same status for the same reasons in a military context, as we will see.

From the perspective here described it should be clear why New Economy entrepreneurs were so enthusiastic about Metcalfe's insight into network effects. For businesses and investors monopoly status is the Holy Grail, and Metcalfe's Law was a map with a big bold "X". Once critical mass is achieved, a product susceptible to Metcalfe's Law gains substantial advantage over the competition: the utility of the network grows with each new user, extending its advantage each time by the logic of n^2 and leaving the competition farther and farther behind on the competitive landscape. Note how this

¹³ To be clear, there is considerable criticism of the very concept of *lock in* as asserted by New Economy theory, and likewise of the phenomenon of path dependency that will be discussed in the next section. Stan Liebowitz and Steve Margolis, have been especially critical, arguing that there is no basis to accept the existence of any such phenomena, and we find their work compelling. It should be noted, though, that Liebowitz and Margolis restrict their scepticism to efficient markets consisting of rational actors, and allow that the phenomenon might still occur in inefficient markets. Military decision-making falls within this latter category, and thus we consider these phenomena to be plausible in a military context. Much of the excellent work of these two authors is available on line, and can be accessed through Stan Liebowitz' web site at UT Dallas.

process poses potentially adverse implications for the consumer of the network. Having embraced the dominant standard, and helped to push healthy competition from the field, there is the alleged phenomenon of lock-in with which consumers must grapple. According to New Economy theory, membership in a network creates a special obstacle to change: traditional switching costs that are, insofar as information-based networks are concerned, typically high, and perhaps as important the lost utility that ensues from leaving the network. So, Metcalfe's Law is the generous friend of the owner of the network, and network effects are a boon for business. But for the consumer this is a potential trap.

The military corollary of the foregoing should now be clear, and it should likewise be clear that the traditional characterization of increasing returns and lock-in in the NCW literature has missed the important point. Metcalfe's Law tells us that if all else is sufficiently equal we should adopt the network with the most users. There is no use pretending that there will be options here. The networks that inevitably lead according to this criterion will be US-owned networks, or those coalition networks that have been approved, and will likely be led by, US forces. This, in itself, is neither good nor bad: it is just the natural consequence of US military dominance. Nor is it something that we can change. US forces have every right to exert their influence in this domain. Moreover it should be noted that this preference even locks in the options of US forces themselves: the logic that drives coalition partners to favour US led networks likewise drives US forces to prefer their own networks. Our choice of US owned, or US endorsed and dominated networks is simply a rational one and the only option we have is to manage the consequences wisely. But what are those consequences?

We say of the phenomenon at issue here that it is a "policy trap" to underscore the fact that according to the logic of Metcalfe's Law, when an organization joins a network it surrenders its freedom in an important and unique way. Consider the situation that junior membership in the network entails. Because it does not own the network it has no guarantee of influence over subsequent technical and policy-related issues affecting that network. All sorts of important policy choices are now in the hands of the owner or dominant member of the network. For example, the upgrade cycle, policy concerning information sharing, policy concerning whether the network will be brought to bear in specific circumstances, indeed, even the junior member's continued right to participate in the network are all in the hands of the owner of the network. And yet, high switching costs and the cost of losing the utility of the network in question locks it in: creating a barrier to leaving that is higher than would be the case where network effects were not at play. The unvarnished fact of the matter is that the phenomenon of lock-in asserted to derive from Metcalfe's Law gives the owner of the network significant power over the network's junior members. It is difficult enough to address the up-front implications of network standardization. But the real threat to the junior partner is the *future* decisions that the owner of the network is in principle always free to make without consultation, limited only by a purely voluntary choice to take the views of the junior members into consideration. Given that no sovereign government or senior military leadership need consider past agreements binding, the guarantees provided at the outset of any arrangement are no guarantees at all. Cebrowski's clear mistreatment of the concepts of

lock in and lock out distracts our attention from a vitally important consideration that all autonomous actors must consider as a matter of highest importance wherever they value their autonomy. The first step in the process of joining a network is a tough round of hard-nosed negotiations involving a complex contract. The second step is vigilance.

We will close this discussion by clarifying our own position. Nothing in the foregoing should be taken to imply the view that networks and networking are necessarily bad. It is the theory of Network Centric Warfare to which we object, not information and communications technology. Moreover, we believe that when properly exploited, networks and networking offer great promise. But NCW proponents have made serious mistakes in their business analogy; and this is but one of them. The mischaracterization of increasing returns and lock in distracts our attention from a valuable insight. It would be imprudent in the extreme to enter into a network without appreciating the potentially adverse stakes and thus without seeking appropriate safeguards.

The Third Problem: Metcalfe's Law is a Capability Trap

The problem to which we now turn our attention was implicit in the foregoing section, but since its consequences manifest themselves in a distinct way, we have chosen to treat it separately. The phenomenon at issue here is called *path dependency*: an adverse implication of network effects that has troubling implications for NCW-inspired military transformation. Let's take a quick look.

The urgency with which NCW advocates view their programme is not debatable. According to their outlook, the fundamental transformation of warfare is already underway. Moreover, this transformation is purportedly inevitable and its parameters are purportedly clear in the technological and economic phenomena that we have been exploring in this chapter. NCW advocates are thus in a considerable hurry. In *Information Age Transformation: Getting to a 21st Century Military*, for example, Alberts exhibits a widespread attitude of impatience. He criticizes what he calls "a conservative approach [of proceeding] slowly and systematically, thoroughly testing proposed alternatives until the probability of error is acceptably low"¹⁴ and implies that circumstances demand a more aggressive approach, called co-evolution: rapid concurrent progress on all fronts, including research, capital, doctrine, training and the like. The attitude here is quite clearly that we know enough about what we have to do to move quickly without undue risk. While the paternity of this impatient attitude is less clear, it seems likely that it is at least in part a manifestation of the New Economy's emphasis on speed that, as we saw, was in turn the result of a Metcalfe-inspired race to critical mass. No doubt, there is also a degree of self-confidence in the intellectual strength of the NCW thesis behind this impatience.

The problem with this aggressive approach is that it appears to overlook a New Economy insight called *path dependency*. According to this insight, networks are super-sensitive to their initial conditions. In other words, the concept of path dependency warns us that if we make a mistake in early decisions concerning the specifications of what will

¹⁴ David S. Alberts, *Information Age Transformation: Getting to a 21st Century Military*, p 26.

eventually become the dominant network, then we are “locked-in” or “stuck with it” more so than would be the case with goods and services that are not subject to network effects. In his misstated discussion of the subject, Cebrowski even uses one of the stock New Economy illustrations of this phenomenon: the infamous and untrue urban legend of the QWERTY keyboard¹⁵. The economic causes of path dependency were implicit in our discussions in the preceding section: the utility of a network is a high cost to pay for leaving the network, and switching costs are high where information networks are concerned.

Yet again we find how an improved business analogy appears to yield an important and potentially adverse lesson. On the one hand, NCW proponents are in a hurry to implement network centric transformation. And yet the logic of their theory yields an overlooked phenomenon of hidden amplified risk. Path dependency does not rule out ‘moving fast and accepting risk’. But we suggest that the concept of path dependency deserves being pointed out by the New Economy’s military enthusiasts, and that it should be part of the deliberate calculations of military transformers.¹⁶

The Fourth Problem: Metcalfe’s Law Breaks Down at Sufficiently Large ‘n’

Of all of the adverse lessons of the restated business analogy presented here, we submit that the phenomenon to which we now turn is the single most devastating of all. It is also central to our own thesis and introduces a theme to which we will return in our critique of the NCW perfect information programme, and in our proposed alternative model for information technology exploitation later in this report. This is so because the phenomenon before us flatly contradicts the very essence of the NCW programme; namely, the quest for dramatic improvement in military capability through a ubiquitous network and ubiquitous networking. Let us explain.

Metcalfe’s equation is a simple accelerating upward polynomial: an unending slope moving ever higher at an increasing rate. As previously discussed, the economic significance of this slope rested in its seeming promise to reverse the frustrating tendency of the market to deliver ultimately diminishing returns on production, at least for certain key industrial sectors, for Metcalfe’s curve seems to promise increasing returns and, by inference, either the end, or at least the sharp amelioration of the defining boom and bust cycle of the market economy. It is precisely this anticipation of increasing returns in the context of Metcalfe’s Law that Cebrowski and Gartska elaborate upon at length in the article to which we have been referring. Moreover, this feature of Metcalfe’s Law is precisely the one that leads them to measure the ‘robustness’ of a network by the variable

¹⁵ The story of the QWERTY keyboard was frequently repeated in New Economy theory as a simple historical example of the phenomenon of path dependency. According to the legend, the QWERTY keyboard was originally deliberately designed to be inefficient and slow, in order to discourage typists from typing so fast that the mechanism jammed. As the story goes, this safety measure is no longer needed, but because we are all used to the QWERTY keyboard, we are locked into the standard: notwithstanding that more efficient keyboard layouts have been designed and demonstrated. However, research by Liebowitz and Margolis, casts this story into great discredit.

¹⁶ We repeat the caution mentioned at footnote 13, above, that there is sophisticated argumentation against the concept of path dependency, but under market conditions that do not apply in a military case.

'*n*': for Metcalfe's Law seems to imply that there is no upper limit to the accelerating benefit of additional network nodes and, thus, 'the more the merrier'. Alberts *et al* do not make the analogy as literally as did Cebrowski and Gartska; nonetheless, their depiction of Metcalfe's Law is identical to that of New Economy theory and they clearly share the goal of a ubiquitous network. The lesson in all of this is clear: for proponents of the NCW thesis, Metcalfe's Law justifies the quest to place the maximum possible number of battlefield actors on one interconnected network in order to enjoy the military equivalent of the New Economy's purported "increasing returns".

But alas, contrary to this popular depiction, Metcalfe's Law *is not* a smooth upward curve growing unboundedly. The contemporary consensus in the economic literature is that Metcalfe's Law actually breaks down at sufficiently large '*n*', at best flattening out the curve and at worst turning it back down at some sufficiently large number of users¹⁷. In other words, Metcalfe's Law does not promise increasing returns. Ultimately the rate of increasing value derived from additional new users slows and it is possible that the value of the network may actually start to decline with additional users. There are three reasons for the new assertion that Metcalfe's Law breaks down at sufficiently large '*n*'. All will be familiar to the reader. First, as subscription to and presence on the network increases, searching the network becomes increasingly difficult. Anyone who has conducted a search on the Internet recently, beyond the narrow circle of favourite sites, will have experienced this phenomenon: a search engine can easily deliver more hits than could conceivably be consulted, while a highly specific query that narrows the results to consumable levels will almost certainly miss pages that actually are of interest¹⁸. Second, as use of the network increases it becomes congested, making it less responsive as a means of transmission. So, as subscription and use increase on a network, difficulties in conducting searches for relevant information and delays in transmission and responsiveness due to congestion act as a potential drag on the network's value, dampening the growth in value even to the point of tipping the curve downward. Third, the limitations on the ability to assimilate and effectively process information of both human and machine constrain the growth of meaningful interactions. This limitation is more elementary than the mere clock rate of the microprocessor; rather, it relates to fundamental constraints on the efficiency of procedures for processing the information, and ultimately to whether suitable procedures even exist at all¹⁹.

¹⁷ A good discussion of this phenomenon is available on line. See Paul Windrum and G.M. Peter Swann, "Networks, Noise and Web Navigation: sustaining Metcalfe's Law through Technological Innovation", 1999, at <http://www-edocs.unimaas.nl/files/mer99009.pdf>.

¹⁸ One important factor that limits web search relates to the unrelentingly increasing complexity of the query that is needed to deliver exactly the intended result.

¹⁹ Gödel shattered two thousand years of tradition in 1931 with the publication of his incompleteness theorems. Turing later showed that there are no reasoning procedures for answering arbitrary questions even in straightforward number theory. The consequence of this is that there are many problems for which there is simply no possible process of solution. Even for those problems that can be solved, many are intractable in the sense that the procedures for solving them require profoundly unreasonable amounts of memory and time. Numerous apparently simple problems of enormous practical significance are known to be unsolvable, and no efficient process of solution is known for scores of others. Most researchers believe that none can exist in these cases. In fact, the issue of whether such problems do have efficient solution methods or not is believed to itself be an unsolvable problem.

Does Metcalfe's self destruction in economics have a parallel in a military application? In order to answer this question let's extend the economic analogy with three additional economic concepts: supply, demand and the diminishing marginal cost curve. On the one hand, and for reasons that we will address in our second paper, military doctrine in general and the NCW thesis in particular place a high value on information: it is billed as the font of knowledge and the progenitor of certainty²⁰. In a sense, then, military culture has an ***unlimited demand for information***. Now consider a second economic phenomenon known as the diminishing marginal cost curve. One of the remarkable consequences of digitization is that whereas the first data element is extremely expensive to produce given the investment required to acquire or create it and then digitize it, the cost of subsequent copies of this data element drops dramatically and remains obscenely low. For example, it costs a lot to put the first copy of a phone book on a compact disc, but thereafter it costs virtually nothing to produce subsequent copies of the phone book. As a result, information becomes dirt-cheap – data can be copied and distributed at virtually no cost once it is acquired – and there are no meaningful limits on its available quantity. In economic terms then, with the network we combine *unlimited demand for information* with ***unlimited supply of information***.

Standing between this unlimited demand for, and unlimited supply of information in the world of the ubiquitous military network is Metcalfe's self-destruction at sufficiently large 'n' and two bothersome questions: how are we to process all of this data and how are we to transport it? The depiction of Metcalfe's Law in the NCW literature distracts us from this ultimate obstacle to the NCW programme. The value of a network does not increase *ad infinitum* at an accelerating pace, as is typically maintained; instead, the outcome is a point at which the benefit of adding another node or another data element to the network may actually diminish the rate of increasing value for the network, and beyond that a point at which a new node or a new data element may actually turn the curve into a diminishing slope. We already know this phenomenon well in a military context. Information overload, an insatiable demand for bandwidth and the increasing need for specialist organizations and resources to perform the information and intelligence and battlefield information management functions are but three symptoms of this phenomenon: this phenomenon is not in the future, it is with us now and it will remain with us for so long as the NCW thesis remains with us. With no limit to the demand for data in the NCW thesis as it presently stands, and with no limit to our supply of data thanks to the diminishing marginal cost curve, what limits are there to information overload²¹ and the resource requirements of information transmission and management? And since we have yet to establish the benefit of the pervasive and indiscriminate networking demanded by the NCW thesis, how do we know where and to what extent the

²⁰ See, for example, Alberts et al, *Network Centric Warfare: Developing and Leveraging Information Superiority*, op cit. p 127.

²¹ NCW proponents attempt to sidestep the difficulties raised here by propounding a partial 'pull' or 'post then process' approach to information. This is no solution. At very large 'n' we must deal with the phenomenon of difficult search, which is merely another form of information overload. Whether information is pulled or pushed between participants, we are faced with fundamental limitations on our ability to assimilate and process information, whether by man or machine.

returns on our investment are worthwhile²²? Just as private industry did in the 1990s, are we allowing New Economy theory to lead us into the wastefulness of serious over-capitalization in information technology? On the whole this is a non-trivial challenge for the NCW thesis: if the logic of Metcalfe's Law self-destructs, then the NCW thesis self-destructs.

The lesson we draw here is perhaps the central insight that we offer in this series of papers, and we will return to it repeatedly in a variety of different ways. The best, and indeed the only way to avoid the self destruction of the network and to maximize its benefit is to limit the only variable at our disposal in Metcalfe's Law. This variable is 'n': a proxy for the very ubiquity of the network so central to the NCW thesis. The simple solution, upon which we will elaborate in subsequent papers, is to ***set limits by making choices***. We must limit the network, we must limit interconnectivity, and we must limit information. All of these seem contrary to the NCW thesis, and yet they are the lessons of its own business analogy.

The Fifth Problem: The Gains are Asymmetrical

There is a second respect in which the seemingly flawed conventional depiction of Metcalfe's accelerating slope discussed above distracts our attention from an important insight. As it turns out, the benefits from networking are not uniform for all members of the network. There is a fundamental difference in the value equation for early and late adopters of the network, and it is a significant matter that some nodes are 'more equal' than others. Alberts *et al* come close to recognizing the importance of this detail, but we submit that they fail to pursue it to its richest conclusion.

Alberts *et al* acknowledge that Metcalfe's Law only necessarily holds if we assume that all nodes on a network are of equal value and that this assumption is unjustified²³. By admitting that nodes are of asymmetric value, we admit that the prospect of increasing returns, upon which the NCW thesis has placed so much faith, is no longer the necessary outcome, which undermines the argument in favour of ubiquitous networking. As it turns out, there is compelling argument in the literature, called *de Long's Law* by some, that makes precisely this assertion; namely, that in practice there is a difference between the values of nodes and that the most valuable nodes on a network will tend to be occupied first. Under these conditions, the rate of growth in utility of the network may diminish, or even reverse.

But there is a more important insight here, as well: one that potentially puts the actual purpose of the network at question. What are the most valuable nodes on the military network? Who gains the most from the various capabilities that information technology can deliver on the battlefield? Whose disadvantage is assuaged to the greatest extent?

²² Of course, the proponents of NCW assert that the great benefit of information sharing is self-evident. We will criticize that position in the next chapter.

²³ See the discussion at *ibid*, appendix A

We chose not to pursue this line of questioning in a geopolitical context²⁴, but to focus on generic military functions. The answer to these questions in this latter context rests in recognition of the fact that the NCW thesis is expressly a *command and control* initiative. We submit that the NCW thesis is valued most by commanders and all the more so as the level of command increases, and we cannot conceive of any reasonable objection to this assertion given the frank statements to this effect in the NCW literature. The NCW approach implicitly seeks to emulate centralized control using what is actually a distributed system. In other words, the aim appears to be a system that operates the same as if were centralized, but without physically centralizing its elements²⁵. The notion of a ubiquitous Common Operating Picture that provides the same information to everyone is one obvious symptom of this vision of effectively centralized command and control in an environment where its elements are geographically dispersed.

In this sense, and against denials by the NCW proponents, we see no conceivable convincing objection to the following claim: the NCW thesis as it stands is an energetic exercise in centralization and positive control. And the irony of this conclusion is that it is made necessary by the logic of Metcalfe's Law, which NCW proponents themselves invoke. There is any number of circumstances in which a soldier gains nothing from the existence of a network, as would be the case, for example, while he was in the process of bayoneting an opponent. But there are no circumstances in command and control where the same could be said.

But note a final irony here. For commanders – the early adopters with seemingly the most to gain from populating the command and control network – there is a further insight. As two theorists have noted²⁶, the early adopters are also the ones most likely to encounter diminishing returns first as the network's population increases. It is a case of being careful what you ask for. It will be some time before we connect the seamless information highway down to the level of individual rifleman. When this happens we are confident that these rifleman will put this new capability to some beneficial use (or they *accidentally* break it). But long before this happens, this ubiquitous monster will overwhelm its early adopters: the top-level commanders who value it most. Already the cost of managing the copious data and interconnectivity of the network is heavy, manifest

²⁴ It must be pointed out, again without implying criticism, that US forces are the early adopters of the NCW ubiquitous network. The ensuing discussion thus has a parallel in a geo-political context.

²⁵ In fact this is yet another well-beaten path that the NCW thesis has mistakenly chosen to follow. The early days of computer science were focussed largely on the development of software that would operate on the centralized computer systems of the day. With the proliferation of networks of computers, thoughts shifted to the development of software operating across different machines, and initial work in this area during the middle of the 1980s aimed at making the network of machines appear the same to software developers as the familiar centralized mainframe environment. That is, early research in distributed systems attempted to *emulate* a centralized computer using what is actually a distributed computer system. By around 1990, it was clear that this is unachievable, and application software developers were becoming increasingly comfortable with their more complex networked environments anyhow. The new vision that drives distributed computer system research to this day is that of providing software developers with an elegant model of the network environment while hiding the tedious and complex details of how communication between software modules running on different machines actually occurs.

²⁶ Windrom and Swann, op cit.

in information overload, increasing bandwidth requirements, and expensive fusion capability. Imagine how bad the situation will become when every soldier is plugged in.

We wish our point to be clearly understood. We are *not* asserting that the NCW thesis is necessarily flawed simply because it supports centralization and positive control. We are *not* asserting that centralization and positive control are necessarily bad. What we *are* asserting is this: the misapplication of a flawed business analogy has once again damaged the NCW thesis and concealed from us a matter that otherwise demands careful consideration. The NCW thesis apparently *is* an exercise in centralization and positive control, and all of the assertions to the contrary in the literature simply fail to alter this perception. Under these conditions it is absolutely essential to confront and consider the consequences of our actions in a mature and sophisticated way. To what extent, how and where do centralization and positive control improve military action? Under what conditions, if any, are they ill advised? What are their adverse consequences and how can these be mitigated? To the extent that we wish to pursue this course, how might it fail and how can any obstacles be managed if at all? We would do well to give these questions careful consideration.

Two Lesser Problems: Coase and Capital Budgeting

In the course of our research we encountered a number of additional problems related to the business analogy. The constraints on length for a paper of this kind preclude their exhaustive investigation here. But we will mention two in brief. First, there are serious economic grounds to restrain the anticipation of impending radical Internet-enable business restructure and the demise of the traditional firm. Likewise there are grounds to resist the assertion that the network is a sufficient and necessary condition for profound change in traditional military organizational models. The relevant economic concept here is Coase's Theory of the Firm, one of two insights by this renowned economists that would eventually win him the Nobel Prize. According to Coase, the firm exists, and takes the form that it does for good economic reasons: it is the most efficient solution to the problem of transaction costs, and over the long run the size and shape of the firm will be driven by optimal cost benefit in this domain. As it happens, network-enabled collaboration addresses only part of these transaction costs. Other transaction costs include the cost of recruitment, of search, of trust and of policing. As it turns out, insofar as network-enabled restructure is concerned, there appear to be important limits on our prudent freedom of action. There is a difference between could and should.

An old-fashioned problem related to capital budgeting is also relevant here. Indeed, it is one of the bases upon which the validity of the business analogy, to we referred at the outset, can be challenged. Very briefly, there is an important difference between industry and government insofar as the freedom to invest in any capital project, including information technology projects, is concerned. Industries have access to the capital markets and thus there is no theoretical upper limit on their access to capital. When considering an investment in information technology, the only relevant financial consideration is whether the return sufficiently offsets the cost. If so, and if the capital markets agree, any and all investments are theoretically possible.

But military forces do not have access to the capital markets. Instead, they exist under conditions of capital rationing: an imposed upper limit on their access to capital. This lends a new degree of complexity to investment decisions in a military organization. Information technology will always be only one of our important investment requirements. Ours is a complex, inter-related programme with many conflicting needs to satisfy, all within an ultimate cap on capital. Under these conditions we are not as free to invest in the promise of information technology, no matter how impressive its billing and no matter how large the budget, for we must presumably still purchase weapons and ammunition, to cite two obvious competing demands. We must place careful limits on our investments in information technology, a fact that makes demonstrated benefit all the more important. Once again we find grounds, in the restated business analogy, to reign in our enthusiasm for a network-enabled, technology-driven information age military transformation.

Conclusion: Picking up the Pieces of the Business Analogy

We commend NCW advocates for the courage to look as far afield as business theory in their quest for military insight, for we believe that too much of the history of military thought has been an inward looking exercise. Moreover, we commend their efforts to promote the utilization of advanced information technology on the battlefield, and to press for the principle of beneficial change. We share the view that the emergence of modern information technology is a development of great significance and grant the possibility that it may hold great disruptive potential, both for good and ill. But we contend that the precise nature of this potential and how to best implement change remain open to dispute. As we have seen, the NCW business analogy is unsatisfactory. Indeed, in many instances the lessons of a critical business analogy contradict the very essence of the NCW programme. Proponents of the NCW thesis must deal with these challenges.

We contend that the basic parameters of an alternative to the NCW thesis have begun to emerge in the foregoing criticism of the business analogy. Moreover, we submit that the basic outline of this alternative programme is already clearly distinct from the vision that currently dominates military theory. We summarize the lessons of the restated business analogy as follows:

1. ***Ratchet down the rhetoric.*** The NCW thesis has gained a large and enthusiastic following and has a considerable amount of institutional momentum. Yet, as we have seen, a critical appraisal of one of its important components – the NCW business analogy – appears to yield troubling and contrary results. We submit that even when viewed from the partial perspective of the business analogy the case has not yet been made. The situation appears to call for caution and further critical review, before the NCW programme as it presently stands is embraced as a basis for military decisions and actions.
2. ***There are no silver bullets.*** Military organizations are amongst the most complex of modern human institutions and military activity is likewise amongst the most complex of human undertakings. Neither can be reduced to a few simple

- phenomena, or a few problematic laws. Information technology is but one of the variables in the complex equation of information age warfare. Warfare is not “network centric”. It is either “people centric” or it has no centre at all.
3. ***The business case is not manifest.*** No credible business case has been made for ubiquitous connectivity on a ubiquitous military network. Metcalfe’s Law does not describe the gains to be had from network-enabled military interactions. We require a sense for how and where networking improves military performance before we can justify the expense of networking and the disruption and expense of collateral change. In the process we should also consider how and where networks and networking have an adverse affect on military performance.
 4. ***Ubiquity is contra-indicated.*** Just as Metcalfe’s Law breaks down at sufficiently large ‘*n*’, so does the benefit of the military network and of military networking have its upper limits. Indeed, the need to limit the network emerges as one of the most surprising inferences from the business analogy. In sharp contrast to the NCW thesis, it even raises the possibility that we may justify a preference for smaller, diverse autonomous networks with constrained or no interconnections between them, and it hints that the goal of a common operating picture was flawed from the outset. Moreover, it makes clear the need to limit data holdings and information exchange, a point to which we will return.
 5. ***Command networks centralize.*** There are compelling reasons to conclude, both from Metcalfe’s Law and from the nature of the NCW programme itself, that the NCW thesis implies substantial centralization of authority and control. Insofar as Metcalfe’s Law is concerned, it appears that early adopters gain most from a network, at least at the outset, and commanders are the early adopters of the ubiquitous network. It also bears mentioning that because of the phenomenon of asymmetric gains, a command-driven agenda of ubiquitous network participation may limit gains to commanders themselves. Insofar as the NCW programme is concerned, it appears to seek the goal of replicating central control and authority albeit in a distributed fashion through such vehicles as the common operating picture. Centralization of control and authority requires careful consideration and should not be entered into casually. In subsequent papers we will argue that centralization of the form resulting from the NCW thesis is in fact adverse.
 6. ***Networks are a threat to friendly forces.*** The phenomenon of ‘lock-in’ and ‘lock-out’, to the extent that they are credible, pose a significant challenge to network design and policy. Technical decisions related to the design of networks must be made carefully, for the phenomenon of path dependency may lock participants into a deficient network. Moreover, junior members should not lightly enter into networks. Strong guarantees of influence over the subsequent development and use of the network must be achieved at the outset, and vigilance is required thereafter.
 7. ***The organizational implications are limited.*** A compelling case can be made that traditional military organizations and hierarchies have evolved over time as an efficient response to transaction costs. Since a network addresses only some of these traditional transaction costs, it is logical to conclude that the justified organizational impact of networks will be limited. Other variables are at play and must be taken into account.

8. *The decisions will be difficult.* Even where a compelling business case can be made for information technology, capital investment in this domain must, as elsewhere, be constrained. Military forces exist under conditions of capital rationing and must satisfy a large and diverse programme with scarce resources. The requirement is to seek an effective balance in resource expenditure.

Just as the NCW business analogy appears unsatisfactory, so too are both it and an improved business analogy insufficient. Indeed, some readers may be attracted to the NCW thesis for an entirely different reason and may be unaware of the important influence of the business analogy or deem it irrelevant. For them, and others, it may be the second feature of the NCW thesis – which we call the NCW perfect information programme – that attracts their favourable attention. It could be argued, for instance, that the enormous cognitive benefits of large-scale information sharing may obviate less important concerns related to the mere economics of networks and information. To this whole notion, and to its extraordinary origins, we now turn our attention.