Metrics for NCW-Related Investment

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Abstract

This paper discusses the availability and suitability of metrics for Network-Centric Warfare to inform investment and transformation decisions. Four types of progressively more complex investment decisions were considered: 1) choosing between two similar capabilities, 2) choosing between two network-centric capabilities, 3) choosing between a network-centric capability and a non-networked capability and 4) determining areas in which to invest in order to improve network-centric capabilities and force effectiveness. Using a simple tactical problem to develop initial insights into the investment domain, network-centric metrics, such as those in the Network Centric Operations Conceptual Framework, were found to be most suited to the first type of investment decision. Some of the metrics in the framework, such as those related to agility and force effectiveness, provide the foundation for comparison between different capabilities and for systems-of-systems analysis. However, they cannot be used in isolation. Even when restricted to an analysis of network-centric capabilities, the metrics in the framework need to be augmented with additional considerations of the capabilities under analysis, the relationships between the metrics, other capabilities and operational concepts. Type 3 analysis currently requires a detailed comparison, which may be based on analytical analysis, simulation or experimentation. Type 4 investment analysts should also consider the use of metrics specifically designed to capture potential redundancies and excesses of capability.

1. Introduction

Australia, like a lot of other countries, is trying to adjust to changes in the military environment, both in terms of the range and uncertainty in the threats faced and to take advantage of changes in technology. Countries are trying to decide how to transform, and the costs and benefits of various change strategies. This is a significant challenge, both due to the financial investment involved (almost one quarter (24.8%) of the 2003-2004 Australian Defence budget is allocated to the procurement of military equipment [ADO, 2003]) and the complexity of the analysis involved. For many capabilities, the Defence community has an intuitive feel for the benefits of different procurement options, particularly when those capabilities support "traditional" warfare. The Defence community may even have data and operational experience to support or supplement these beliefs. However, when the capabilities are relatively new, or changes to operational concepts are planned, as when capabilities and doctrine are planned to co-evolve, there is little relevant data and the intuitive perspective is often missing or misleading. Such is the case for Network-Centric Warfare capabilities.

[1] This paper is based on research conducted while the author was attached to RAND.

Researchers have tried to quantify the benefits of Network-Centric Warfare. Examples include the benefits in a maritime missile defence scenario [Perry et al, 2003] and a ground warfare scenario [Dekker, 2002]. While these approaches provide some guidance for specific investment decisions, the analysis is difficult if not impossible to generalize. In 2002, a framework of metrics was developed with the objective of quantifying the benefits of NCW [Signori et al, 2003].

The initial version of this framework was designed to capture metrics in areas that have previously been poorly addressed – with a particular emphasis on Command and Control metrics, and to a lesser extent Intelligence, Surveillance and Reconnaissance metrics. Over 150 metrics were identified. The framework has been shown to be useful in quantifying the benefit of adding NCW capabilities (in this case Link-16) to an existing capability package [Gonzales et al, 2003].

The framework developers intended it to evolve as it was applied to a variety of problems associated with force transformation. The investment challenge discussed in this paper is one such challenge.

This paper looks at the strengths and limitations of the metrics in the framework in this context. It proposes a range of metrics that may need to be added to the framework to support investment decisions and provides some insights into the processes that need to be in place to support investment analyses.

2. **Investment**

Four typical investment decisions, which become progressively more complex, were considered.

1) *Choosing between two similar NCW capabilities*. In this type of investment decision, we assume that the required capabilities have already been decided and that alternative systems to deliver that capability are under review. For example, we may know that we need a sensor, a command and control (C2) system, communications system or improved network connectivity. This type of decision may be conducted, for example, within an acquisition project and is typically conducted using metrics for the particular capability domain.

2) *Choosing between two different NCW capabilities.* In this type of investment decision, we are comparing two capabilities that have a different impact on the force. This includes comparing one type of capability (eg sensor, C2, communications system) against another, as well as comparing the application of a particular type of capability to different areas of the force. This type of analysis may be conducted within a capability development domain.

3) *Choosing between a network-centric capability and a non-networked capability.* This type of investment decision occurs when higher-level committees compare the capabilities selected from within each capability development domain.

4) *Determining areas in which to invest to improve force effectiveness through improvements in NCW capabilities.* This type of investment decision is based on determining areas that would benefit from investment, even if there are currently no systems under consideration. One

way to achieve this is to rely on innovation. However, in this case we are interested in the ability to objectively determine areas worthy of future investment.

These types of investment decisions cannot be completely separated; for example, developing a roadmap for future NCW capability investments may include analyses of types 1, 2 and 4.

In this paper, we consider each type of investment separately, as we are primarily interested in whether the available metrics are suitable for assessing the value of the capabilities (including the concepts of operation) under consideration. We do not consider the full complexity of the investment process including the need to balance current and future capabilities or the availability of funding over time. Additional metrics, which should be consistent (at least in their generic form) across capabilities, are needed to consider these issues.

Even determining the benefit associated with a single capability (or capability package) is complex. There is uncertainty in the range of threats that will be faced, and in the evolution of the technology that effect the evolution of the capability, the ability to counter it, in competing technologies that make the capability obsolete, and in the other capabilities with which the capability will have to operate. Furthermore, a military may not have control over the capabilities with which they have to operate; for example, operations may involve coalition partners, other government departments and non-government or aid organizations. A capability needs to be agile in order to deal with this uncertainty. Agility is often assessed by the ability of a capability to perform well under a range of conditions – including dynamic environments, force mixes, tasking etc. Research into how best to assess agility is ongoing, but two possible approaches are 1) to develop a parameterized scenario that covers the scenario space of interest, and 2) use a range of scenarios, to assess the capabilities, or investment options, of interest. The scenarios or scenario space could cover a range of threats, socio-political environments, and capabilities (including possible future capabilities) with which the capabilities of interest have to operate. In either case, assessment of capabilities against a scenario is required. This paper develops initial insights into the different levels of investment analysis by considering some simple comparisons of capabilities based on a simple notional scenario together with some investment options.

The simple scenario selected for this paper is a tactical force-on-force engagement. Analysis using other types of scenario including more complex tactical force-on-force engagements, peacekeeping scenarios, manoeuvre together with strategic and operational-scenarios covering effects-based operations etc could also be considered.

3. An Illustrative Example

Figure 1 provides an illustrative example of three current blue force capabilities (solid blue circles A-C) in a hypothetical scenario against 6 red assets (solid red circles a-f). The blue circles indicate the Intelligence, Surveillance and Reconnaissance (ISR) range of the blue assets and the red circles their engagement range. For the purposes of this example, we are not concerned about the type of engagement or ISR capability, only their ranges. Asset B has a high ISR capability and a limited engagement capability. Asset C has the largest engagement range, but unless it receives additional ISR information, its effective engagement range is limited to its

ISR range. Asset A has the same ISR range as Asset B, but does not suffer from this problem as it has an engagement range that is just smaller than its ISR range.

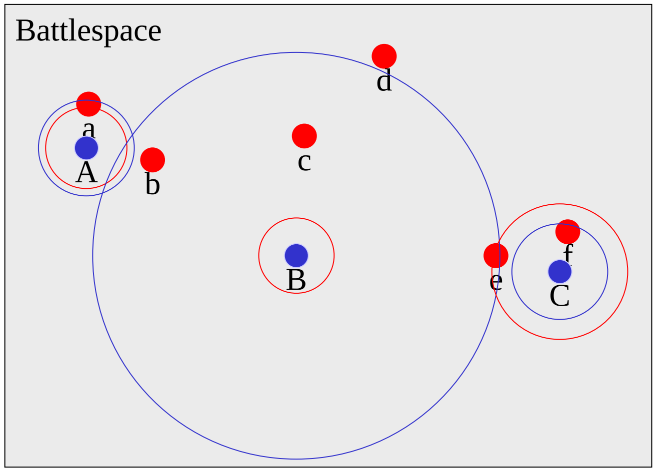

Figure 1: Base Capabilities

Assume now that we have a certain amount of money that we can allocate to upgrading this capability package. Assume further that this money can be allocated to one of the known upgrade paths, or to investigate a new upgrade path.

Let the known upgrade paths be as follows:

1. Network A, B and C with high-bandwidth connections A-B and B-C.

2. Network A, B and C with medium bandwidth connections A-B, B-C and A-C.

3. Upgrade the ISR range of B to the entire battlespace.

4. Upgrade the effectiveness of A's weapon system.

A comparison between 1 and 2 falls into the first category of investments, between 1 or 2 and 3 into the second and between 1, 2 or 3 and 4 into the third. The fourth category concerns the identification of new upgrade paths. In this simple example, it is obvious that upgrading the ISR range of C so that it covers at least the engagement range should also be considered. In practice, possible upgrade paths are not normally this easy to identify and it would be useful if the metrics could provide some insight into potentially beneficial upgrades – in all aspects of Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF).

We now look at the available NCW metrics and their suitability for each of these analyses.

4. Network-Centric Warfare, Investment and the Illustrative Example

In this analysis, we consider only the metrics in the NCO CF (Signori et al, 2004), although we believe that the results are more generally applicable. This framework is based on the tenets of Network Centric Warfare and it was designed to determine the degree to which a force, or mission capability package (MCP), reflects the NCW concepts and capabilities and how these contribute to overall effectiveness. It is believed to be one of the most comprehensive available containing over 150 metrics. Even so, the metrics are intended to be generic high-level metrics and the authors of the NCO CF recognize that additional metrics may be required when the framework is applied. This paper provides initial insight into the nature of those additional metrics for investment analyses, as well as suggesting some additions to the NCO CF metrics.

In general, we do not need to know the details of the metrics; it is sufficient to consider a rough comparison based on the capabilities captured by the framework, as shown in Figure 2. Those metrics that are required will be introduced in the relevant part of the text.

The capabilities covered by the framework are further grouped into 6 measurement areas to simplify the analysis.

1) *Organic Information*, which as in the framework covers the quality of information at its source – whether a sensor or a human source.

2) *Networking*, which as in the framework covers both the network and the ability of the nodes to connect to and use the network. However, in the grouping, we also include *Information Share-ability* or the ability of the nodes to exchange information.

3) *Individual and Shared Information,* which covers all information available to either single participants or groups of participants (these are covered separately in the framework).

4) *Individual and Shared Sensemaking,* which covers individuals' and groups' (these are covered separately in the framework) awareness, knowledge and decisions.

5) *Synchronization,* which covers the coordination in time, space and intent of planned and actual (these are covered separately in the framework) actions and locations of entities.

6) *Effectiveness,* which as in the framework covers the achievement of objectives, and the timeliness and cost of these achievements.

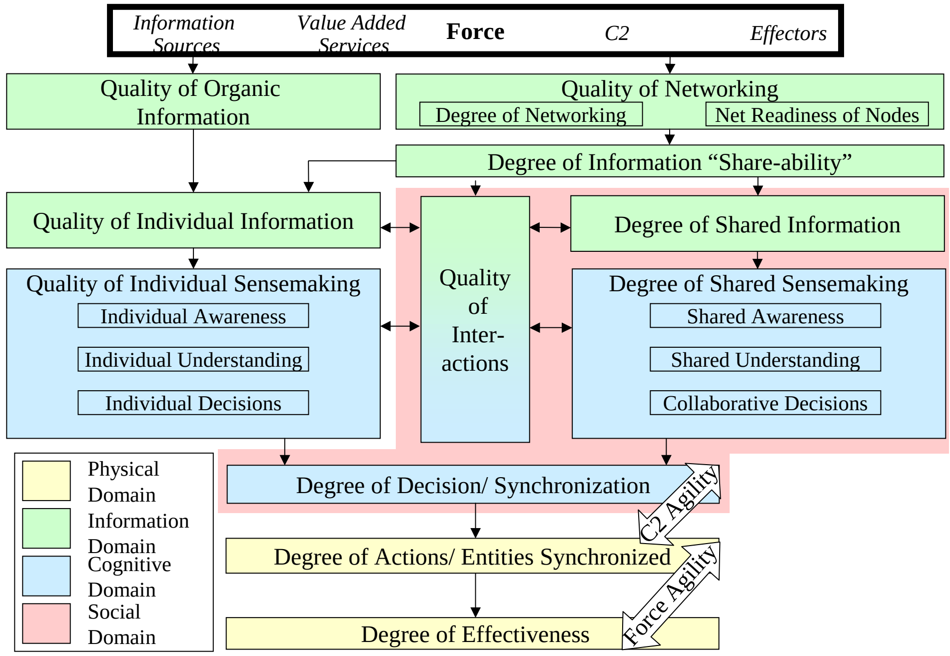

Figure 2: Network-Centric Operations Conceptual Framework (Top Level)

4.1 *Similar Capabilities*

We return to the illustrative example previously introduced and consider the addition of a high bandwidth network with connections A-B and B-C or a medium bandwidth network with connections A-B, A-C and B-C.

Networking allows for the exchange of information between the blue assets. In this example, both networks connect all of the nodes (this is captured by the *reach* metric in the framework), but the second network has a redundant connection, and is thus more resilient to failure in any one of the connections (captured by *resilience* in the framework). The other difference between the networks is the bandwidth (captured by *quality of service* in the framework). To determine the impact of these differences, we need some figures. We assume that a medium bandwidth[2] connection supports data exchange at 1 information exchange per time unit and a high bandwidth connection supports data exchange at 1.5 information exchanges per time unit. Thus, both networks have a total bandwidth of 3 information exchanges per time unit. However, this need not lead to the same degree of information share-ability since in the first network, communications between A and C need to go over two links. If there exists information that needs to be communicated between A and C, and not to B, this decreases the effective (and the average) available bandwidth and the total quantity of information that can be posted and retrieved[3] using the network.

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[2] Depending on additional implementation decisions, a low bandwidth may result in some information not being distributed, a delay in the distribution of information, or most likely, a lower refresh rate for information.

[3] This terminology is from the framework.

In this example, we assume that we want to exchange information equally between all participants, and thus in both cases we have the bandwidth to support an identical increase in the information available at each node as follows. We assume that the 8 pieces of known information (both red and blue locations) are distributed as often as possible to the two nodes that do not possess the information, giving 16 information exchanges. Since the networks can only support 3 information exchanges per unit time, only 19% of the information is exchanged during any time unit.

Figure 3 summarizes the analysis based on the framework[4]. The impact of the changes is clearly shown at measurement areas 1: Organic Information and 2: Networking. Although, because we have assumed no direct exchanges between A and C, there are no difference at the higher-numbered measurement areas, except for those related to Agility (that is resilience to connection failures), which is better in the second network. It is therefore assumed that, all else being equal, the second network would result in the same or a greater improvement to combat effectiveness. From this, it is clear that a comparative analysis using only the lower-numbered measurement areas is sufficient for this type of investment analysis.

Measurement Area	**High bandwidth A-B, B-C**	**Medium bandwidth A-B, A-C, B-C**
1. Organic Information	No Change Completeness of A 0.22 Completeness of B 0.44 Completeness of C 0.22	
2. Networking	Reach goes from 0.0 to 1.0 Total bandwith 9 information exchanges/time unit Vulnerable to connection failures Limited ability to share information	Reach goes from 0.0 to 1.0 Total bandwith 9 information exchanges/time unit Resilient to failure of one connection Increased ability to share information
3. Individual and Shared Information	Completeness goes from 0.29 to 0.40 Improved information Vulnerable to connection failures	Completeness goes from 0.29 to 0.40 Improved information Resilient to failure of one connection
4. Individual and Shared Sensemaking	Improved Sensemaking Vulnerable to connection failures	Improved Sensemaking Resilient to failure of one connection
5. Synchronization	Improved synchronization Vulnerable to connection failures	Improved synchronization Resilient to failure of one connection
6. Effectiveness	Improved effectiveness Earlier engagements* Vulnerable to connection failures	Improved effectiveness Earlier engagements* Resilient to failure of one connection

* These improvements derived from considerations of the illustrative example are not explicit in the NCO CF.

Figure 3: Comparison of Similar Capabilities

[4] Note that the danger with using these metrics (eg for individual information) for a particular scenario is that the values are highly dependent on the relative locations of the red and blue assets. The scenario in Figure 1 was carefully chosen so that both A and B's ISR assets detected exactly one red asset. In practice, a wider scenario space is required for a more realistic analysis and to allow for sensitivity analysis.

4.2 *Network-Centric Capabilities*

The previous example was very simple. In reality, changes to a network are likely to involve more than a change in connectivity and bandwidth, but also differences in the quality of service, network assurance etc. In this section, we examine a more complex example, where comparisons need to be made between sensors and a network. The lessons from this analysis will be equally applicable to comparisons between very different networks.

Figure 4 summarizes the analysis. In this case, we have assumed that the increase in the ISR capabilities of B were sufficient to span the entire area of operations. As in the previous example, the NCO CF is able to quantify the differences at measurement areas 1-3 in the framework. Comparing the results for Individual Information, Networking A, B and C appears to be inferior. (Analysis of Shared Information requires some additional assumptions on what constitutes sharing, and is not shown.)

Measurement Area	**Medium bandwidth A-B, A-C, B-C**	**Increase ISR Capability of B**
1. Organic Information	No Change Completeness of A 0.22 Completeness of B 0.44 Completeness of C 0.22	Completeness for B goes from 0.44 to 1 Completeness of A unchanged, 0.17 Completeness of C unchanged, 0.17
2. Networking	Reach goes from 0.0 to 1.0 Total bandwidth 9 units/second Resilient to failure of one connection Increased ability to share information	Networking Reach unchanged, 0.0 Total bandwidth 0 units/second No change in ability to share information
3. Individual and Shared Information	Completeness goes from 0.29 to 0.40	Completeness goes from 0.29 to 0.48
4. Individual and Shared Sensemaking	Improved in sensemaking at A, B and C Improved positioning decisions at A, B and C* More engagement decisions at C*	Greater improvement in sensemaking at B Greater improvements in positioning decisions at B*
5. Synchronization	Greater improvements in synchronization of A, B and C	Improved synchronization (through B only)
6. Effectiveness	Improved effectiveness Earlier engagements*	Improved effectiveness

* These improvements derived from considerations of the illustrative example are not explicit in the NCO CF.

Figure 4: Comparison of Network-Centric Capabilities

However, this does not necessarily correspond to an increase in performance for B at the higher-measurement areas in the framework. In the case of network, each of the nodes has additional information that potentially improves their sensemaking including their ability to position themselves and, in the case of C, engage additional targets such as “e”. In the case of the improved ISR performance, B has complete information and can determine its best position, but this is of limited benefit since B’s engagement range is very small. B can attempt to coordinate (synchronize) with A and C, but neither would be aware of B’s attempts until B came within sensor range. In contrast, A, B and C would know each others' locations 19% of the time, and would be able to attempt a degree of synchronization.

The increases in the quality and speed of positioning decisions for all force elements, together with the greater increase in synchronization and engagement decisions, are expected to lead to a greater increase in effectiveness with the addition of the network than for the improved ISR capability.

The NCO CF metrics are suitable for this comparison, although significant additional information was required, including the relationship between the information and engagement ranges. That is, an understanding of exogenous, or non-network-centric variables and their relationship to the network-centric variables is required. It is anticipated that analyses that are more complex would also require a greater understanding of the concept of operations.

This is not unexpected; the current version of the NCO CF is only intended to capture the key NCW metrics, and not to specify the relationships between all possible metrics. Two groups of additional metrics can clearly be identified – (I) those related to the NCW capabilities of the MCP, which fall roughly in groups 1-4, and (II) those required to calculate the more general metrics in the higher-numbered groups (4-6). Both groups of metrics are required for investment analysis because the MCP does not exist and so the metrics in the NCO CF cannot be directly assessed and thus need to be computed; they may not be required in applications where the NCO CF metrics can be directly assessed.

4.3 *Network-Centric and Other Capabilities*

The NCO CF metrics were designed to capture network-centric capability, and so it is not surprising that they fail to capture the impact of changes to other capabilities until the higher numbered-measurement areas: Individual and Shared Sense-making, Synchronization and Effectiveness. In this scenario, upgrading A's weapon system has no impact until the final effectiveness, as shown in Figure 5[5]. Networking A, B and C shows the improvements previously discussed, allowing for earlier engagements and better pre-positioning, and increased synchronization, which should also reduce the duration of the mission and the damage incurred during engagements. Upgrading the weapon system should increase the efficiency of engagements, reduce the time spent in engagements and, as with Networking A, B and C, it should reduce the damage incurred during engagements.

It is difficult to determine which of these capabilities is better. In particular, a detailed understanding of additional variables and metrics, and a more comprehensive understanding of the concepts of operation and situations in which the capabilities would be deployed is required. The following simple analysis highlights some of the additional requirements.

First, sufficient metrics and relationships need to be incorporated into the model to capture the benefits of the weapons system on force effectiveness. The traditional metrics for weapons systems is the probability of kill. Suppose that the improvements in the weapons systems

[5] In practice, a change to a weapon systems effectiveness is likely to change the range of circumstances under which the decision maker is willing to use the weapon.

increase the probability of kill from 0.2 to 0.25. The change in the average number of rounds faced is minor, with an approximate drop from 4.8 to 4.6 rounds. Determining the impact of this change, however, requires an understanding of how it affects the combat outcome – such as the percentage of troops injured etc – which may depend of a variety of factors including the concept of operations and the capability of the enemy not explicitly captured in the framework. An understanding of these factors would augment Group II of the additional metrics identified for the previous investment analysis.

Measurement Area	**Upgrade the Effectiveness of A's Weapon System**	**Medium bandwidth A-B, A-C, B-C**
1. Organic Information	No Change Completeness of A 0.22 Completeness of B 0.44 Completeness of C 0.22	
2. Networking	No change	Reach goes from 0.0 to 1.0 Total bandwidth 9 units/second Resilient to failure of one connection Increased ability to share information
3. Individual and Shared Information	No change	Completeness goes from 0.29 to 0.40
4. Individual and Shared Sensemaking	No change	Improved in sensemaking at A, B and C Improved positioning decisions at A, B and C* More engagement decisions at C*
5. Synchronization	No change	Greater improvements in synchronization of A, B and C
6. Effectiveness	More effective and efficient engagements (4.8 rounds faced versus 4.6) Improved effectiveness?	Earlier engagements* Improved effectiveness

Figure 5:Comparison on a Network-Centric and a Non-Network-Centric Capability.

Furthermore, this level of analysis is required if we are to compare the new weapons system with the networking of A, B and C.

Improvements in networking result in two sources of improvement in engagements that might be directly comparable to that of the weapons system – the ability to synchronize actions and the ability of C to engage additional targets such as e.

The force elements share information 19% of the time so, assuming a random distribution of information, both know each others' locations only 4% of the time. To determine when synchronization occurs, we need to understand how often synchronization will occur based on the circumstances and the concept of operations. For example, suppose that for 25% of this time (or 1% of the total time) they are able to synchronize their efforts. Then during this 1% of time, the effective fire-power is doubled, halving the number of rounds faced to 2.4 rounds. However, since this occurs only 1% of the time, on average, the number of rounds faced is only marginally lowered, and is still approximately 4.8 rounds.

This analysis is overly simplistic, since it ignores the fact that the weapons and sensor ranges for the blue force elements are different. The need to understand the impact of these factors becomes clear when we consider the impact of C's ability to engage target "e". In order to understand this impact, we need to know how it affects the risk of C being engaged, injured and killed. For example, if the enemy weapons systems have an engagement range much less than C's ISR range and a low mobility, then C should be still be able to engage at a distance and overwhelm them. Conversely, if the enemy can engage beyond C's weapons system range, then increasing C's ISR capability to match its weapon range is not sufficient as they will still be vulnerable to attacks from enemies that they cannot locate. The benefit of C's enhanced ISR capability will depend on how vulnerable they are to attack, the enemies' weapon systems and engagement capabilities, and their ability to conceal themselves, conduct ambushes etc.

To truly understand the impact of these alternative proposals, a significant understanding of the range of capabilities to be engaged, and those of the blue forces under consideration is required. This is not limited to understanding the network-centric capabilities and those under comparison, but the relationships between network-centric, weapons and maneuver capabilities and the concept of operations.

However, this is not to imply that the NCO CF should include metrics for weapons systems or cover all possible concepts of operation, but rather to highlight that analysts need to understand that the framework requires augmentation for this type of analysis.

4.4 *Investment Areas*

Given the difficulties highlighted in the previous example, it is not surprising that determining areas for future investment is problematic. Figure 6 shows the network-centric measures for the base case. Based on this information we can see that there is no networking, a limited ability for the individual assets to collect information, and no shared information (other than information received prior to when the assets dispersed). It is difficult to determine how these contribute to sensemaking and eventually effectiveness. Based on this analysis, the only avenues for improvements suggested are those directly related to network-centric warfare, and even then, their benefits are not necessarily clear:

- Since the value of the metric for shared information is 0 for all assets, networking is likely to result in significant benefits. Since B has the highest quality (completeness) of organic information, networking them to A and/or C should be the first priority (although networking A, B and C with a lower bandwidth connection has a higher Agility as seen previously).

- Increase the organic information completeness (other quality metrics were not considered in this analysis) of one or more of the blue assets.

Measurement Area	**A**	**B**	**C**
1. Organic Information	Completeness 0.22	Completeness 0.44	Completeness 0.22
2. Networking	None	None	None
3. Individual and Shared Information	Completeness 0.22	Completeness 0.44	Completeness 0.22
4. Individual and Shared Sensemaking	0	0	0
5. Synchronization			
6. Effectiveness	Incidental		

Figure 6: Network centric warfare indicators

For the most part, the analysis in this paper has been restricted to comparing weapons range and information distribution. The previous analyses have shown that it is necessary to consider the relationship between the two to determine the impact of network-centric capabilities. Figure 7 lists some basic data and raw comparisons, which suggests some additional or more refined areas for consideration:

- Networking will not result in complete situation awareness (no-one is able to detect red asset d).
- Asset C should have the highest priority for improved sensor capability or networking since its weapons requirements are not met.
- Adding another ISR asset, provided they were networked to existing assets, could further enhance situation awareness. This could be an alternative to extending the range of existing ISR assets.
- Increase the weapons range of asset B, which has the greatest situation awareness.

Measurement Area	**A**	**B**	**C**
ISR range	1.00	4.25	1.00
Weapons range	0.85	0.80	1.40
ISR requirements (Sufficient organic ISR)	Overlapping organic information 0. Total organic information across all assets = 0.88		
Weapons requirements (Sufficient ISR)	Met	Exceeded	Not Met Range limitations

Figure 7: Indicators derived from previous analyses

None of these suggestions is particularly novel – all could be determined by a simple analysis of the problem. However, the purpose of the paper is to highlight the limitations in restricting investment analysis to those covered by network-centric metrics and frameworks. Figure 8 suggests some areas for consideration in this fourth type of investment analysis in addition to those derived from the previous analyses as given in Figure 7. As discussed below, consideration of some of these areas would also be useful in other types of investment analysis.

Scope and utilization of Information	Duplication of information Coverage of organic information
Utilization of Personnel and network-centric equipment	Overlap in participants roles and/or activities Utilization of personnel; cognitive workload; activity in a given role Network load
Other capabilities	Relationship between information availability and requirements - eg for weapons, C2, etc
Degree of Transformation[6]	Changes in DOTMLPF in response to equipment changes including changes to C2, the use of control measures, and concepts of operation (and vice versa). Doctrine versus practice
Mission (Transformation) Objectives[7]	Distance to halt invading army under conditions of early anti-access Distance to halt a maneuvering division Time to stop ethnic cleansing Fraction of critical enemy fixed and mobile targets that can be held at risk from D-Day Probability of achieving OPLAN objectives in spite of WMD threats Offshore distance US can reliably determine intent of, and interdict, potential threats Fraction of population that falls within potential reach of deployed defenses Probability of zero threat warhead leakage Percentage of shortfall in local/state/federal consequence management response capabilities met by at-home military units Time to restore mission-critical facilities and networks following attack Percentage of critical DoD information technology

Figure 8: Additional Indicators

These metrics cover three broad areas: those that might be considered for inclusion in future versions of the NCO CF, those that relate network-centric to other capabilities, and those related to transformation goals and objectives. The first two categories in Figure 8 are the most suitable for inclusion in a network-centric framework and are based on the idea that capability developments should be balanced, that is, that identifying and fixing limiting capabilities is more important than improving other capabilities. These may be useful for all 4 types of investment analysis, but particularly for type 4 analyses. The third is required for any of the type 2-4 investment analysis and involves understanding the relationships between all the capabilities, not just between network-centric capabilities. It is unlikely that any domain-driven framework will capture these. The fourth is related, and is based on the belief that transforming one area is not sufficient; when any equipment is changed, C2 and operational concepts need to be changed to gain the most benefit and there may be related metrics that could be both added to the NCO CF and used in analyses between capabilities. The fifth is also related to transformation, but is based

[6] These are suggested because DOTMLPF changes often lag behind equipment changes, and failure to consider them may result in sub-optimal performance and incomplete capability requirements definitions.

[7] These are taken from [Kelly et al, 2003].

on analysis of more specific transformation goals. As previously stated, this set, and the entire list, is not intended to be exhaustive, but to illustrate the range of attributes and metrics not covered by the existing network-centric metrics and the NCO CF in particular.

5. Conclusions

This paper has argued the network-centric metrics developed to date, and in particular those in the NCO Conceptual Framework are not sufficient by themselves for the full range of investment analyses required by Defence. A few suggestions for improvements to the framework have been given, but generally, what is required for investment analyses is an acknowledgement that network-centric capabilities cannot be considered in isolation from other capabilities – with the possible exception of very similar capabilities. The investment analysis problem is particularly challenging because the MCPs under consideration generally do not exist and so values for the metrics in the framework need to be calculated rather than observed. Several additional groups of metrics and considerations have been identified:

1. Consideration of factors that determine the NCW capabilities of the MCP

2. Consideration of factors that determine how NCW and other capabilities affect force effectiveness

3. Metrics that capture the balance of capabilities, including areas of over- and under-utilization.

4. Metrics that capture the degree and balance of transformation.

5. Metrics that capture the degree and balance of transformation against transformation objectives.

Of these, some additional metrics from the third and fourth categories could be included in the NCO CF. The latter two groups should not be included as they are specific to the transformation application, and the last group is likely to be time-dependent. The first two categories are likely to require a much more detailed understanding than could be captured in any set of metrics. For example, the full implications of an operational concept and the relationships between capabilities – such as network-centric, weapons and maneuver capabilities – need to be understood in order to achieve an effective investment analysis and it is unlikely that these can be completely captured by any set of metrics.

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