Identifying Essential Technologies for Network-Centric Warfare

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Network-centric warfare (NCW) is still a concept that is being defined; many find it too intangible for comfort. This is an attempt at materializing what, exactly, will be the important technologies for NCW.

Most people's first encounter with the term *network-centric warfare* (NCW) ought to set off their undefined-buzz-word-that-sounds-fancy radar. It appears sufficiently generic an expression to encompass any computer-based warfighting system. It is true that there is no dictionary definition of the term. This calls for a clarification of the sense it will have in this article: *NCW is about leveraging existing information assets using an infostructure.*

Now, let us dissect this statement: The term infostructure is an amalgamation of the words *information* and *infrastructure* – it refers to the infrastructure used for information sharing. This could be anything from a long-wave military radio network to an office Local Area Network (LAN). The next keyphrase is *existing information assets*. This establishes that NCW is not about creating new information, but rather about using the information that is already in our possession. Finally, the word *leveraging* is of crucial importance: We are trying to make better use of what we already have. Based on these premises, NCW is about creating battlespace superiority through more efficient use of existing information.

The concept of NCW can be further illustrated by an example. Think of a situation where Army tanks, Navy ships carrying short-range missiles, and Air Force ground attack aircraft would be deployed to take out a mobile enemy command unit. Rather than each moving independently toward the target, they would use a common data network to coordinate their efforts. Each unit type has various sensors to track the target, and this data is fed into the data network. The data is processed into one single target reading that is returned to the units, rendering much more accurate positioning. As the units move in closer to the target, they all have the friendly tank positions plotted on their map displays to avoid friendly fire incidents. The Navy ships have real-time information on the location of the attack aircraft as the ships get ready to launch their missiles. Finally, when weapons are launched, all units receive continuous feeds on the status of the target to optimize impact.

Clearly this way of taking out the target is more likely to have favorable results at a lower cost compared to a situation where all units act independently. It is made possible through intelligent sharing of information.

> *"NCW [network-centric warfare] primarily focuses on … enabling better awareness of the enemy and friendly forces – but also places emphasis on improving command and control and decision making as well as execution … through improved communications systems."*

What will it take, technically, to achieve this battlespace superiority? This article attempts to materialize what, specifically, the crucial components are for making it possible to reap the benefits of NCW. The approach is general, not focusing specifically on the United States or any other military force.

The Functions in NCW

In their book "Network-Centric Warfare" [1], the authors identify three roles in the battlespace (*battlespace* as opposed to *battlefield* reflects the reality that today's battles are not necessarily fought in a single geographically delimited theater). These roles carry out the three main functions – or tasks – in the battlespace: 1) achieving battlespace awareness and knowledge, 2) command and control and decision making, and 3) execution.

These functions are carried out by the *roles* of sensors, decision-makers, and actors, respectively. The concept of NCW primarily focuses on the first of the functions – enabling better awareness of the enemy and friendly forces – but also places emphasis on improving command and control and decision making as well as execution, for instance, through improved communications systems.

An illustrative example of these functions is a forward-deployed reconnaissance squad determining the exact location of a target (*sensor*) and reporting this back to the command center. At the command center, the order is given (*decision-maker*) to an aircraft in the area to take out the target (*actor*).

At the other end of the spectrum, the three roles can be carried out by one and the same entity: An infantry soldier spots an enemy soldier (sensor), determines that he needs to attack the enemy soldier (decision-maker), and proceeds to fire his weapon against him (actor).

Analysis Based on the NCW Roles

Splitting the analysis along these functions is a good inroad to trying to determine what it will take for NCW to be a success. Of particular interest to this community is the first function: How to achieve battlespace awareness and knowledge. This function is not an effort to gather more information; remember, we are in the business of better using our *existing* information assets. Rather, it is an attempt to share and process information in the best way possible. The remainder of this article will consist of a closer look at the sensor function.

Battlespace Awareness and Knowledge Analysis Methodology

This research is an attempt at formalizing the analysis of key technological areas for enabling NCW: How do we find the *hottest* information sharing nodes where exchange of sensor data is the most valuable? It presents a methodology for creating a relative ranking of the information sharing nodes. The following is a description of that methodology.

The key to the approach was to start with a complete model of the battlespace and from there, try to *zero in* on the most interesting areas from a NCW perspective. The chosen model would describe all the possible transactions between information nodes in the battlespace such as depicted in Figure 1. An information node was equated with any battlespace entity (aircraft carrier, fighter aircraft, armored personnel carrier). Using a ranking methodology, the most interesting of these nodes would be identified.

The basis for the graph in Figure 1 was a matrix that described all the possible information transactions. An information transaction involves an information supplier and an information recipient. The information supplier translates into a sensor, as described earlier, carried by some battlespace entity. The information recipient corresponds to any battlespace entity. For instance, there could be an aircraft carrying photoreconnaissance equipment (*information supplier*), transmitting image data to a ground unit charged with the task of taking out a target (*information recipient*).

By applying mathematical methods as described further on in this article, the value of each information transaction could be assigned a relative value, which in turn formed the basis for a graph with rankings.

Initially, a list of all main unit types in the battlespace from sources such as [2] was created. For each of these unit types, a list of all possible categories of sensors that could be carried was assembled. From this, a matrix (Figure 2) was compiled to describe the value of all possible information transactions between the entities in the list. This approach was inspired by John J. Garstka's method of representing information positions [3]. Along the x-axis of the matrix are listed all possible suppliers of information such as air radar carried by an attack aircraft or global positioning system (GPS) carried by an armored personnel carrier. Along the y-axis are all possible information recipients such as bomber aircraft or submarine.

Each element i_{jk} represents the value of information flow from element k to element j, for example, the value of information flow from attack aircraft air radar to a bomber aircraft. In the study, each element was assigned an integer value between 0 (low importance) and 2 (high importance) to determine the significance of the information transaction.

Additionally, each column was multiplied with a weighting factor to indicate the significance of the sensor being carried by a particular unit type – for instance to account for the fact that a surface warfare ship will not necessarily be carrying an air radar (low weighting), while an anti-submarine warfare aircraft is guaranteed to be carrying a sonar (high weighting).

This resulted in a 150 X 25 matrix. The values in this matrix were absolute; that is, they were all measured along the same scale but they had not been adjusted to reflect the relative importance between them. Having the values relative rather than absolute was key to being able to graph their significance. The absolute values were transformed into relative values through the following method:

- In the interest of keeping the results manageable, the matrix data was grouped into aggregate elements according to different rules for each analysis. For instance, one analysis was performed where aggregate groups of transactions based upon the sensor type (e.g., *air radar*) were created, and another analysis was done where groups based on the carrier unit type (e.g., *ground unit*) were compiled.

For illustrative purposes, we will look in more detail at the case where information suppliers were grouped according to the sensor type as well as carrier type.

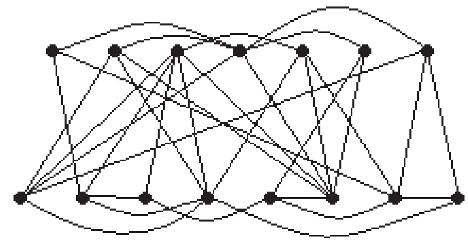

Figure 1: *Information Transaction Graph*

One supplier group was *air radar* carried by air units. In this analysis, one information recipient group was *sea units*. The value to be calculated was thus the relative importance of information flow from air radar carried by an aircraft to a sea unit. The formula was the following:

$$\textbf{Relative Importance} = \frac{\sum \text{Matrix}_{jk}}{\text{Count}}$$

where,

j **is an element of recipient group,**
k **is an element of supplier group,and**
count **is the total number of suppliers in the group.**

The outcome of this calculation is that the relative value was computed as the sum of all matrix elements for air radars carried by aircraft where the information recipient is a sea unit, divided by the number of air radars carried by aircraft.

A Java program was written for these calculations and for formatting the results into inputs for the Graphviz tool from AT&T [4]. Graphviz was then used to produce illustrative graphs such as the one in Figure 3 (see next page).

Figure 2: *Information Transaction Matrix*

Information_supplier

Information_recipient

$$\begin{bmatrix} Weight_1 & Weight_2 & \cdots & Weight_n \\ i_{1,1} & i_{1,2} & \cdots & i_{1,n} \\ i_{2,1} & i_{2,2} & \cdots & i_{2,n} \\ \vdots & \vdots & & \vdots \\ i_{m,1} & i_{m,2} & \cdots & i_{m,n} \end{bmatrix}$$

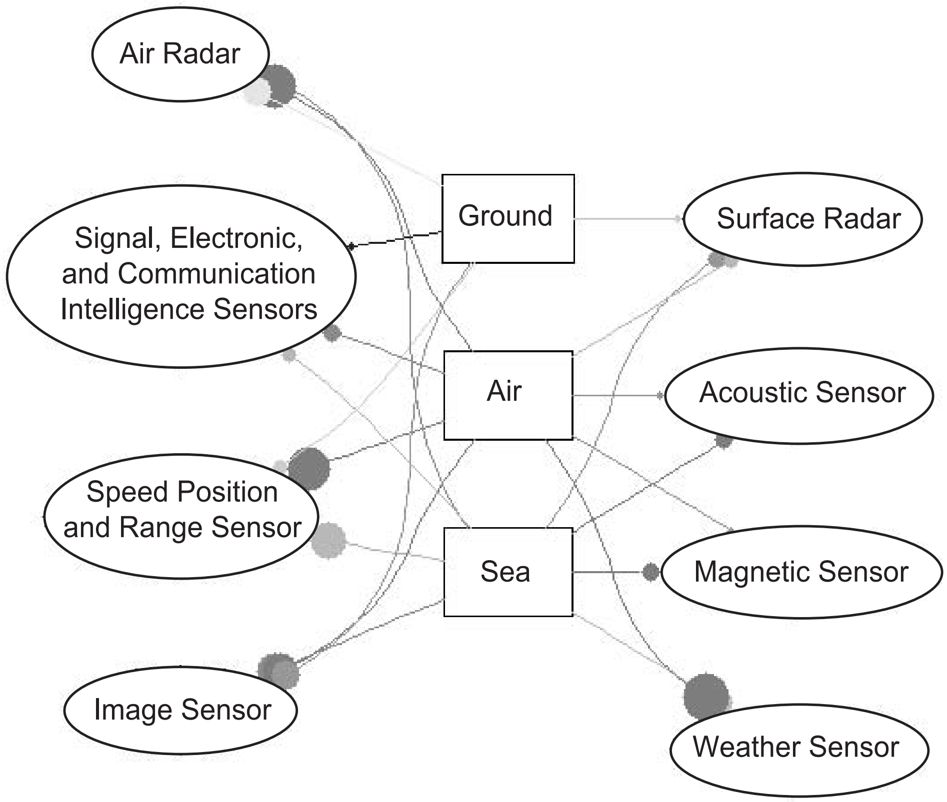

Figure 3: *Information Transaction Matrix*

Results

The graphing resulted in clearly distinguishable areas of interest. For information suppliers, four sensor types were distinctly at the top of the list:

1. Friendly unit positioning sensors.
2. Weather sensors.
3. Enemy positioning sensors.
4. Imaging sensors carried by aircraft.

An example of friendly unit positioning sensors is a GPS system. Friendly units receive a feed from the sensor on the unit's position. This creates a very high level of battlespace awareness of friendly units' whereabouts.

Weather sensors range from temperature sensors to weather radars – anything that may inform other units of the current weather conditions.

Enemy positioning sensors are typically radars. A fighter aircraft may receive a feed from other friendly aircraft tracking the same enemy unit. Creating a fused reading from the friendly aircraft's data indicating where the enemy unit is renders a more accurate positioning and, hence, better efficiency.

Imaging sensors carried by aircraft are sensors that capture either still or video imagery, either visible light or infrared.

On the information recipient side, air and sea units were deemed more interesting than ground units. This reflects the fact that these units typically carry more advanced processing systems and are able to take in information from more sources. It also illustrates the greater necessity for aircraft and ships to be oriented about the whereabouts of all friendly units as well as enemy units.

So what is the impact of these results? We can draw the conclusion that the four sensor types previously identified ought to be among the systems receiving particular emphasis in military acquisitions. Similarly, they are likely to be receiving particular attention by equipment manufacturers. Development of these systems is likely to be prioritized.

One area merits some extra thought from a software viewpoint: Looking particularly at sensor types one and three, data fusion – the art of taking readings on the same phenomenon from several sources and applying algorithms to generate a single, more accurate reading – will be of special interest. The type of data fusion in question here is referred to as *positional fusion* [5]. Three component tasks make up positional fusion:

1. **Data alignment:** Transforming sensor data into a common frame of reference.
2. **Parametric association:** Associating observations into groups that represent the same entity.
3. **State vector estimation:** Combining the observations that result from the same entity into a single estimation of the entity's position and velocity.

Clearly, this is a very processing-intensive area, with a focus on optimized software.

While it might be considered stating the obvious, it should also be pointed out that software areas of general relevance to NCW are, among others, network operating systems, network interface software, and communications applications.

The Next Step

In a look further down the line, one author [6] envisions a departure from direct connections between a sensor and the user. Rather than each unit carrying its own sensors, there would be so-called *data fusion nodes* to which both suppliers and consumers of information would connect. This would be a hub of sorts, with a task manager that, when a request for information arrives, directs the job to the sensor(s) with the best quality, capability, and availability. Data fusion would then be moved away from users into this centralized location.◆

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Additional Reading

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About the Author

David Schaar is a consultant with Booz Allen Hamilton in McLean, Va., where he is a cost analysis consultant with a primary emphasis on Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance systems. This article was written during his previous capacity as a cost research analyst with PRICE Systems, LLC, of Mt. Laurel, N.J., and is based on research performed as part of his master's thesis. At PRICE Systems, Schaar developed an information technology affordability management tool for the company's activity-based costing solution. Schaar has a Master of Science in industrial engineering and management from the Linköping Institute of Technology in Sweden.

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LETTER TO THE EDITOR

Dear CROSSTALK Editor,

Paul McMahon's article, "Bridging Agile and Traditional Development Methods: A Project Management Perspective" in the May 2004 edition of CROSSTALK on bridging between agile and traditional development methods may have missed the real point. An on-site customer representative for a subcontractor in an environment where the customer is encouraged to change requirements can have serious risks, not only for the prime, but also for all of the other subs that have to adjust to those changes. Integration is far harder than straight development precisely because the communication cost of keeping the various pieces working together is large.

Often embracing change means never having to get it right. This has been a primary cause of failure on many so-called agile projects. (The most famous XP project was what should have been a routine payroll system at Chrysler that was cancelled prior to completion due to cost overruns and late deliveries of needed functionality.)

Good up-front architecture and good design mitigate the risks. Both the architecture and the implemented design need to allow for managed change. McMahon does this by adding process weight to agile methods in the form of his recommendations.

Actually, I believe that his modification to the waterfall model, or some other similar modifications, are pretty common to successful development regardless of whether any subcontractors are agile or not.

So, I would contend that the real point of McMahon's article is that successful development is not about adapting to XP by moving toward the middle. It is about the middle being in the right place in the first place because extremes in either direction create extreme risks. The XPers need to move toward the middle as well. If they ever want to build in a true system-of-systems environment, they will recognize that while change is itself a requirement, it needs to be accepted, managed, and controlled, but not embraced.

For a humorous, yet capable, description of the pitfalls (and positives as well) of XP, check out the book "XP Refactored," by Matt Stephens and Doug Rosenberg. It is a combination of clinical dissection and gossipy tell-all about XP. And the only thing extreme about it is the humor.

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