Using Decision Analysis to Increase Commanders' Confidence for Employment of Computer Network Operations

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Editorial Abstract: *This article is an abridged version of a research project by the same name. To read, the full report, please contact the authors.*

Military operations are by their vary nature complex. These activities range from humanitarian operations to homeland defense to various intensities of combat operations. Commanders and their staffs organize, train, exercise and practice for their assigned tasks in preparation of real operations. The tools and tactics deployed and employed during training and exercises become familiar to the commanders and their staffs. Through training, exercises and evaluations, commanders gain an understanding of the capabilities provided and the risks involved in employment. The confidence gained from training and exercises is enhanced during preparation and execution of actual operations.

Information operations (IO) is increasing in importance in military campaigns. The tools and tactics employed in information operations, particularly when enhanced by command, control, communications, computers and intelligence (C4I) advances, are relatively new options available to military commanders. IO plays a significant role in ongoing military operations. *Jane's Defense Weekly*, in an article titled, "US Air Force Refines Information Operations," suggests there are several key lessons the USAF is reviewing. In the article, senior USAF officials are quoted as stating, "one of the most important aspects of the expanding use of IO is the capacity to test and evaluate these capabilities in controlled environments" (Jane's, 2004:10). Another key point emphasized by senior USAF officials was the ability to increase confidence in IO tools within senior leadership:

> …to build confidence among the US Department of Defense's (DoD's) senior leadership in IO systems. The ability to employ these capabilities may migrate in many cases from senior-level positions to the tactical commander in the field, once the leaders are convinced of the reliability and utility of the IO tools… (Jane's, 2004:10).

IO integration requires methods to understand the baseline capabilities provided and the risks involved in employment of emerging tools and tactics. IO capabilities will continue to grow and evolve. A key aspect of IO is Computer Network Operations (CNO). Incorporating lessons learned from Operation IRAQI FREEDOM (OIF) into evolving CNO capabilities will be a challenge.

Currently, CNO is considered to consist of three parts: (1) Computer Network Attack (CNA), (2) Computer Network Defense (CND) and (3) Computer Network Exploitation (CNE). CNA and CND have received the greatest attention from national and international leaders in recent times.

Nature of the Problem

A fundamental problem in the rapid adoption of CNO is to determine methods to increase commanders' confidence in CNO tool and tactics. Are there ways to facilitate communication or define a common understanding of the issue from the operational commanders' perspective so that other key decision makers in the acquisition and evaluation processes can reduce risk, reduce uncertainty and aid in building confidence in newly fielded capabilities? Could this common understanding or framework be used as a baseline starting point to reduce variation in programmatic guidance when leadership changes in all the key jobs?

This paper uses decision analysis techniques, specifically influence diagrams/decision trees, to provide a structure and graphical representation of the problem to support all of the decision makers involved in acquiring, testing and employing CNO tools and tactics. By having a defined structure based on the operational commanders' point of view,

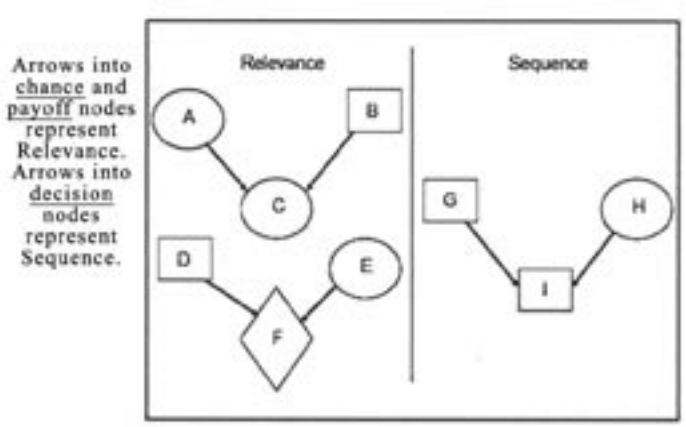

Figure 1: Influence Diagram

the various decision makers impacting the acquisition and test processes (1) gain greater insight on the factors, risks and uncertainties operational commanders face, (2) allows decision makers to work from a common understanding/structure of the problem, and (3) allows better communication flow between the various decision makers. This common understanding/baseline structure becomes more important as the Joint Capabilities Integration and Development System (JCIDS) process evolves.

Decision Analysis

Decision analysis is a method to provide structure and a systematic framework for making hard decisions. Decisions, by their nature, are complex, contain uncertainty and may have more than one objective. Three of the key terms to define in decision analysis are (1) decision, (2) risk and (3) uncertain events. A decision is defined as an irrevocable allocation of resources. Risk as defined in JP 1-02 is the "probability and severity of loss linked to hazards." Uncertain events are defined as events where the outcome is unknown.

An influence diagram was selected to model the decision for employing CNO capabilities. An influence diagram is "a graphic representation of the elements in a decision problem and the relationships among them" (Applied, 1998:6). In an influence diagram, different decision elements are modeled in the diagram as different shapes. In this effort, "yellow rectangles represent decisions, green ovals represent chance events (uncertainties) and blue rounded rectangles represent values" (Applied, 1998:6).

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A decision node represents "an opportunity for decision maker to choose between alternative states of the world" (Applied, 1998:99). A chance node represents an event with two or more outcomes that are uncertain. The chance node "reflects the state-of-information" that a staff or commander/decision maker has about an event (Applied, 1998:155).

Relationships between the different types of nodes are indicated using arrows or arcs. "In general, an arc can represent either relevance or sequence" (Clemen and Reilly, 2001:55). Arcs pointing to decision nodes represent information available at the time of the decision and hence represent sequence and all others represent relevance (Clemen and Reilly, 2001:52-57). Figure 1 shows the difference of relevance and sequence. Arcs/arrows into chance or payoff nodes represent relevance (Clemen and Reilly, 2001:56). "Conditioning" refers to having a conditional probability relationship between events. Wackerly, Mendenhall and Schaeffer describe conditional probability as the "probability (relative frequency of occurrence) of the event given the fact that one or more events have already occurred" (Wackerly, 2002:50). This concept plays a major role in influence diagrams. The relationships represented in an influence diagram are those that are important. Kirkwood points out that influence diagrams reveal more information about the structure of the decision problem than many other representations and are good for studying more complex decisions (Kirkwood, 1997:326-328). The decision to employ any weapon system, especially CNO capabilities, is a complex decision.

The influence diagram described in this section is the result of extensive consultation and interaction with IO and CNO subject matter experts (SMEs) from the Air Force, Navy and Army. These SMEs work within a variety of organizations including the Air Staff, the Army Staff, Air Combat Command, Fleet Information Warfare Center, COMOPTEVFOR, Eighth Air Force, and First Information Operations Command, among others. An influence diagram could be the decision framework for almost any capability, but has been specifically tailored to discuss CNO capabilities, both offensive and defensive. The CNO Employment influence diagram that is the center of this approach is given in Figure 2. This CNO Employment influence diagram models the **decision** whether to employ a particular CNO tool/tactic against a selected target or target set. The purpose of the CNO Employment influence diagram is to capture and investigate the items that influence the decision to employ CNO tools and tactics. The influence diagram developed here provides commanders and decision makers a common framework for discussion and an aid in understanding the very complex problem of whether or

not to employ CNO tools and tactics to attain desired effect(s).

A key consideration is that the CNO Employment model was designed for both CND and CNA. The word, "target," is used in the model and could lead some readers to the conclusion this model is only for offensive operations. The use of "target" is based on its joint definition. As defined in the DoD Dictionary, target is defined as "an area, complex, installation, force, equipment, capability, function, or behavior identified for possible action to support the commander's objectives, guidance, and intent" (JP 1-02, 2003). Threats become targets when action is going to occur against them. For example, a threat to computer systems becomes the target of defensive operations.

Understanding the model and its nodes is an important step for gaining insight and the ability to tailor the model to a given real-world operation. The next sections describe the various components of this model.

options available to the commander. It has been assumed in this preliminary model that in Phases One and Four, CNO tool(s) and tactic(s) have a higher military utility due to the limited choices of kinetic military capabilities available for employment. In all phases of operations, CND tool(s)/tactic(s) are employed to protect information and information systems. In Phase Three, CNO capabilities will compliment other military capabilities both as primary options and as force multipliers. To emphasize this point on using CNA, Denning stated, "Cyber attacks may be used as an ancillary tool in support of other operations…support, but not replace, more conventional military operations" (Denning, 1999:72).

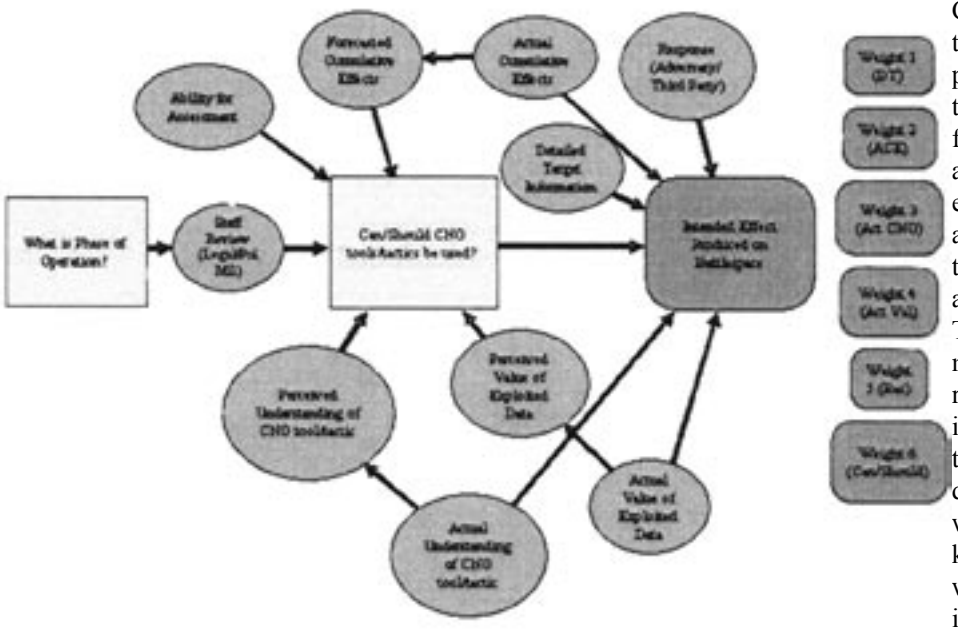

Figure 2: CNO Employment Influence Diagram

What is Phase of Operation? (Decision Node)

The Phase of Operation decision node represents the decision to determine which phase of military operations the commander is in. As stated in JP 3-0, there are traditionally four phases in joint operations; Phase 1 (Deter/Engage), Phase 2 (Seize Initiative), Phase 3 (Decisive Operations) and Phase 4 (Transition). The capabilities available for employment during each phase typically vary. CNO tool(s)/tactic(s) are available in all phases of operations. In some phases, CNO capabilities may be the primary options. In other phases, CNO capabilities are one of many

Staff Review (Legal/Pol Mil) (Chance Node)

The Staff Review chance node represents the uncertainty of whether the CNO tool(s), tactic(s) and the target sets are approved through specific staff review functions. Each CNO tool, tactic and its intended target will be reviewed, at a minimum, by the Political-Military and the Legal portions of the commander's staff to determine whether (1) the CNO tool and/or tactics are allowed to be used based on political situation/sensitivities and any legal restrictions and (2) if the target is sensitive to political issues and qualifies as a legal target by the laws of armed conflict and other treaties.

Ability for Assessment (Chance Node)

The Ability for Assessment chance node represents any uncertainty associated with the ability to get the necessary feedback and determine the success or failure associated with employing the CNO tool(s)/tactic(s) against a particular target/target set. This feedback includes a "munitions effectiveness assessment" and the battle damage assessment. This ability to measure the result of actions is important to phasing, determining whether the non-kinetic response was effective, and in determining the effect(s) on the battlespace.

Forecasted Cumulative Effects (Chance Node)

The Forecasted Cumulative Effects chance node represents the uncertainty associated with *predicting* the cumulative effects produced by a CNO tool(s) and tactic(s) against a specific target or target set. Cumulative effects are defined as "effects that result from the aggregation of direct and indirect effects" (Mann *et al*, 2002:96). Effects include first order, second order, third order and higher effects produced. Subsets of cumulative effects are collateral and cascading effects. Collateral effects are defined as "an unintended/unanticipated effect that results from an action or

set of actions" (Mann *et al*, 2004:95). Cascading effects are defined as "indirect effects that ripple through the system" (Mann *et al*, 2004:95). Cascading effects may be intended or unintended. Cumulative effects contain various key planning factors for employment, including collateral damage, unintended consequences and need for deconfliction.

Perceived Value of Exploited Data (Chance Node)

The Perceived Value of Exploited Data chance node represents the uncertainty associated with the *predicted* value of exploited data gathered through CNE and other intelligence operations. Some governmental organizations consider the term, intelligence gain/loss assessment, as an equivalent term. If data containing intelligence information is coming from a source that is being considered as a potential target, then a commander and his/her staff must evaluate the option of exploiting the source versus employing capabilities against that source. The data coming from the source has some value. This value will depend on the type of target/target set and other factors. In addition, over time, this predicted value may change based on the conduct of the campaign. It will be important for recurring decisions to re-evaluate this predicted value each time the decision is made.

Perceived Understanding of CNO Tool/Tactic (Chance Node)

The operational commanders' and their staffs' perceived understanding of the CNO tool(s) and tactic(s) under consideration will influence their employment considerations. The Perceived Understanding of CNO Tool/Tactic node could evaluate a single tool and a single tactic or could evaluate the combined effect of multiple tools and tactics working together toward a common effect on the battlespace. There are many factors that will contribute to this perception: cost, the type of tool, the type of tactic, level of formal testing accomplished, performance in actual operations and many others. The cost to use the CNO tool and tactic must be accounted for in the perception of its understanding. Cost is a function of money, resources expended, technology exposed, and potentially human lives saved or lost. If a CNO tool and tactic are expensive to employ, there may be other less costly options that alone or in concert with other measures can produce the same or similar effects at a lessen cost.

Can/Should CNO Tools/Tactics be Used? (Decision Node)

This decision node determines whether a selected CNO tool(s)/tactic(s) can be used against a particular target/target set. This node is conditioned upon (1) Staff Review, (2) Ability for Assessment, (3) Forecasted Cumulative Effects, (4) Perceived Value of Exploited Data and (5) Perceived Understanding of CNO Tool/Tactic. The "What is Phase of Operation?" node serves as a military utility factor affecting the resulting values of this decision. All the outcomes of the previously articulated nodes will be known prior to the model evaluating the USE decision.

Detailed Target Information (Chance Node)

The Detailed Target Information chance node represents the uncertainty associated with understanding the target or target set. Intelligence is often imperfect. Denning states that for a CNA "launching it would require considerable knowledge about target systems and interconnectivities" (Denning, 1999: 65). There will be some unknowns and risk associated with the actual target, especially when dealing with CNO.

Actual Understanding of CNO Tool/Tactic (Chance Node)

This chance node represents the level of uncertainty associated with the actual understanding of the CNO tool(s)/tactic(s) under consideration. The outcome of this node is determined after the decision to use CNO capabilities has been made. In the past, there was high risk in employing CNO tools/tactics because the CNO tools or tactics were untested, immature or poorly understood outside of specific circles. In recent years, CNO tools and tactics have undergone increased testing and evaluation events prior to fielding, but the process is still maturing. This node is based on the actual understanding of the CNO tool/tactic used in response to the target/target set that exists at the time of employment.

Actual Value of Exploited Data (Chance Node)

This chance node represents the uncertainty associated with the actual value of the exploited data gathered through CNE and other intelligence operations. The outcome of this node is determined after the decision to use CNO capabilities has been made. As stated earlier some governmental organizations consider the term, intelligence gain/loss assessment, as an equivalent term. This chance node accounts for the tradeoff between the intelligence value of the data versus the value for employing or not employing CNO capabilities.

Actual Cumulative Effects (Chance Node)

This chance node represents the uncertainty associated with the actual effects produced as a result of employing or not employing CNO tools/tactics against a particular target or target set. These effects include known first, second, third and higher order effects produced. For this model, unexpected effects are undesirable outcome(s) even if the contribution to friendly operations is positive

Response (Adversary/Third Party) (Chance Node)

This chance node represents the uncertainty associated with the response by an adversary or third party to the decision. Some of the responses that could be modeled by this node are

(1) "no response," (2) probability of detection, (3) probability of attribution, (4) counterattacks by the adversary and (5) third party responses.

Weights 1-6 (Calculation Nodes)

The weight nodes represent the perception of importance to the operational commander of the six variables feeding into the payoff function. A weight factor is developed for each of the variables feeding into the payoff function. Weight factors provide flexibility in the model as the perception of importance changes for the different variables based on new leadership, new technology, different operational conditions and objectives or a variety of other things.

These nodes have only one outcome, a weight represented as a number. This weight is the percentage of the overall response (i.e. payoff function) their assigned variable represents. The summation of all weight nodes must equal 100%.

Intended Effect Produced on Battlespace (Calculation/Payoff Node)

This payoff node uses an equation that rolls up and scores the overall response to the decision based on all of the factors involved.

Insights Gained from the Decision Model

To demonstrate and test the research, the authors populated the decision model and ran a series of trials to determine the most influential variables within the model. Please reference the paper for the methodology and results.

Operational commanders and decision makers can use this influence diagram to identify key chance nodes. The uncertainty in these chance nodes be can reduced through range infrastructure, force structure investment and other methods (mission rehearsal, deconfliction, forecasting, etc) making future decisions easier. The next sections highlight two strategies for reducing uncertainties, (1) forecasts and (2) test and evaluation.

Reducing Uncertainty in Forecasts

In Figure 2, four nodes in the decision structure serve as forecasts of anticipated and actual outcomes for the decision maker. These nodes are (1) Forecasted Cumulative Effects, (2) Perceived Understanding of CNO Tool/Tactic, (3) Perceived Value of Exploited Data and (4) Ability for Assessment. The first step to increase commanders' confidence in CNO tool(s)/tactic(s) is to ensure instruments or processes exist to provide the required forecasts. Assuming the instrument or process is in place, there must be mechanisms or procedures created and put in place to provide historical data to refine the forecasting instruments or processes. Preferably, such data would be from real-world operations. Forecast models are typically based on historical data. To be effective, the forecasts should produce actionable outputs that predict results close to reality. The greater the forecast error, the greater the risk imposed on the operational commander should he or she select such an approach. Historical data from the last three major contingencies (Kosovo, Afghanistan and Iraq) needs to be fed back into the mission planning system(s), tactics manuals and models used to determine the outputs of these forecasts. This strategy has been employed for some CNO capabilities.

Using Test and Evaluation to Reduce Uncertainty

Test and evaluation serves a role for increasing commanders' confidence in CNO capabilities. Traditionally, developmental test and evaluation has focused on the operation of the system while operational test and evaluation has focused on system performance under combat or operational conditions. As the Department of Defense transitions from a platform-centric viewpoint to a capabilities-based viewpoint, test and evaluation must, and will, evolve. The new Air Force Instruction (AFI) 99-103, *Capabilities Based Test and Evaluation*, incorporates this formal transition. AFI 99-103 states the purpose of test and evaluation is to "…mature systems designs, manage risks, identify and help resolve deficiencies as early as possible and ensure systems are operationally effective and suitable" (AFI 99-103, 2004:6). AFI 99-103 defines capability-based testing as "a mission-focused methodology of verifying that a capabilities solution will enable operations at an acceptable level of risk" (AFI 99-103, 2004:55). In the model, test and evaluation directly contributes to the "Perceived Understanding of CNO tools/tactics" and "Actual Understanding of CNO tools/tactics" nodes. It can also aid in reducing uncertainty in the following nodes as well; (1) Detailed Target Information, (2) Ability for Assessment, (3) Forecast of Cumulative Effects and (4) Actual Cumulative Effects.

CNO tools and tactics, to be fully accepted and become an integrated "arrow in the quiver" of the commander, need to evolve to the point where they are evaluated under a Weapon System Evaluation Program (WSEP) approach. AFI 99-103 describes WSEP as the following:

> WSEP is a tailored type of Force Development Evaluation designed to provide end-to-end evaluation of fielded weapon systems and their support systems using realistic combat scenarios. In addition, WSEP conducts investigative firings to revalidate capability or better understand munitions malfunctions
> (AFI 99-103, 2004: 13)

Such an approach covers the other identified nodes previously mentioned. The support systems for employment of CNO tools/tactics include targeting and assessment. "Firing" CND and CNA tools and tactics will provide data on the cumulative effects produced and predicted. To achieve a WSEP approach, the necessary range infrastructure must be in place to support "firing" of the CNO capabilities.

Summary

Transformation is a difficult action because it drives people outside their comfort zones and embraces change. Today's transformation hinges on more than technology. People must look for new organizations, doctrine and capabilities to meet the new challenges. CNO capabilities will be part of the military's transformation in response to the Information Age. Increasing commanders' confidence in CNO and other non-kinetic capabilities is an absolute requirement if the U.S. military is going to be successful against asymmetric and traditional warfare. Providing a common framework to stimulate discussion between operational commanders, planners and technologists is a key step.

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