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Knowledge Flow Mesh and its Dynamics: A Decision Support Environment

Topic 8: C2 Architectures Track

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ABSTRACT

The exciting advances in modern communications and networking ability have spawned a revolution in decision support systems within the greater network centric framework. Note the ongoing development and operational use of unmanned aerial vehicles (UAVs) in the Global War on Terror and the geographically distributed C2 environment. Sensor saturation and the maturation of mobile technology has advanced at rate in which the current crop of decision and sense making technology has failed to pace against. This leads to one of the most interesting questions pertaining to the current field of decision support systems: Which one is best suited for today's rapidly adapting and evolving network centric tactical situations? In this paper we introduce the concept of knowledge flow mesh dynamics within a decision support environment, which we argue is the logical heir to a new type of decision support system as seen through the network centric lens. Using the ongoing work by the Naval Postgraduate School (NPS) and United States Special Operations Command Tactical Network Topology (TNT) Field Experimentation as a framework for exploration, we offer a systems approach to identifying those criteria which form the basis for the new decision support system. It is our goal that this model be incorporated in future versions of the NPS TNT Field Experiments for validation.

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NPS and USSOCOM Field Experimentation

The arrival of network centric operations (also, *warfare*) has identified a gap in the current field of decision support systems (DSS). This is best exemplified by the current work underway by the United States Special Operations Command (USSOCOM)-Naval Postgraduate School (NPS) Cooperative Field Experimentation Program. As defined by Brigadier General Steven Hashem, United States Army, and director of the United States Special Operations Command Center for Knowledge and Futures, the purpose of the program is to "leverage experiments that identify key gaps and deficiencies resulting from applications of advanced technology, unmanned systems, and net-centric applications". It is this advanced research and proof of concept umbrella that has opened the door for a true decision support environment, one that is the prototype for a new, agile, adaptable decision support environment enabling knowledge flows and situational awareness as viewed through a network-oriented perspective (USSOCOM 2007).

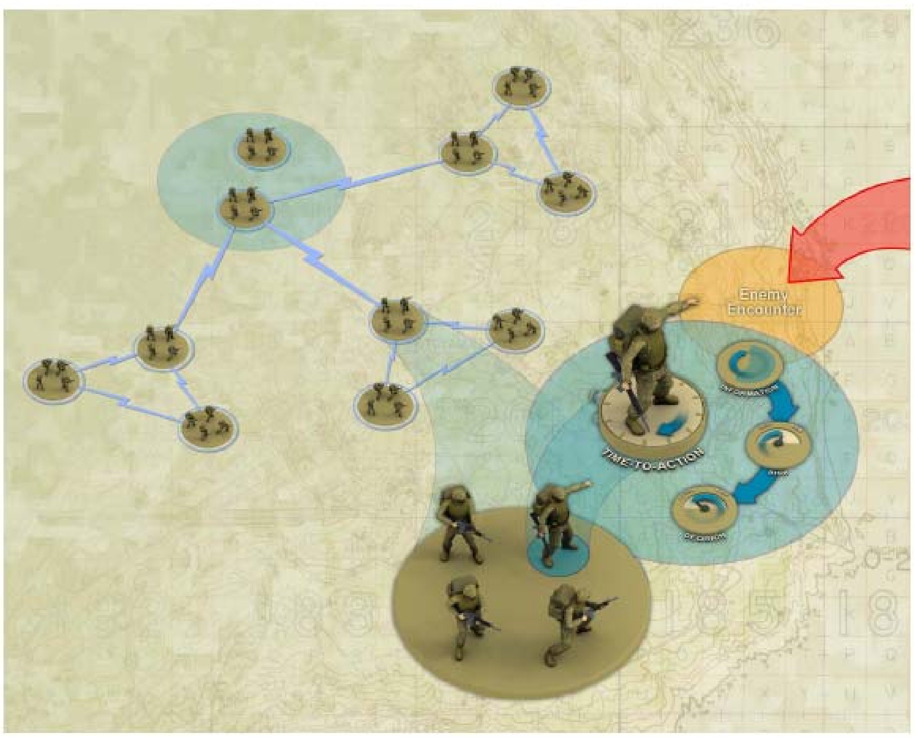
Under the auspices of the Naval Postgraduate School Center for Network Innovation and Experimentation (CENETIX) and its director, Dr. Alex Bordetsky, Associate Professor, NPS, the early work under the joint field experimentation has evolved into what is now known as the Tactical Network Topology (TNT). A number of subset experiments include the Maritime Interdiction Operations (MIO), the Johns Hopkins University / Applied Physics Laboratory (JHU/APL) Fully Autonomous Unmanned Aerial Systems (UAS) Cooperative Search and Tracking, United States Marine Corps (USMC) Distributed Operations, and Unmanned Ariel Vehicle Enhanced Battlefield Medical Situational Awareness and Tactical Networking (Naval Postgraduate School 2007).

In today's dynamic, information rich, and high operational tempo, the need for a robust, resilient, and adaptable decision support environment is greater than ever before. Of particular emphasis here is the context of a "network-centric" approach or lens. Existing literature focuses on the development of the decision support system as a "system" under the control of one or more decision makers (Marakas 2003)). Added to this is the need for a clearly defined problem statement which then, in turn, relates to a particular form of decision support system. The form of DSS is based upon the problem structure, the type of outcome needed, and finally, the type of overhead or control required.

Earlier attempts to bind the characteristics of robust decision support systems with the requisite ability to serve as a knowledge flow enablers to include the ability to adapt and mesh with existing networks and systems have come up short. Articles and conference papers by such leading edge researchers as Bordetsky, Hayes-Roth and Vega, Clements, and Thompson have attempted to either bin the particular DSS as either hybrid (Vega, et al. 2007) or place the functionality onto an architectural structure (Bordetsky, Hayes-Roth 2007).

Specifically, this paper will focus on what we are calling a *Decision Support Environment* within the greater network-centric context which allows for the identification and networking of relevant human and / or machine experts or nodes (who may or may not be an expert all the time but rather at a single, critical moment in time). The ability of the network to connect across geographically distant and sometimes environmentally challenging and operationally difficult domains is of equal interest. In effect, we are trying to enable the dynamic transfer of knowledge across as yet to be determined network topologies and architectures at the right time and location.

What we are saying in effect, is that the current and future networking capabilities to actually bring human decision makers and knowledge experts into the decision environment as "nodes" is an area that shows great potential for future exploration. The human brain is very good at inductive type reasoning and making decision based on internal or "gut feelings" based on experience, judgment and emotion. Computers and decision support systems excel at deductive type reasoning and completing repetitive and routine processing at extremely high speeds. The ability to bring these two together into an operational framework capitalizing on the inherit strengths of each is only now beginning to take shape. Hence the terms "human as a node" and "dynamic knowledge flow mesh" which we offer as new exciting areas of decision support and collaborative environments.



The Proliferation of Decisionmakers

The expanded capacity and adaptability of today's information systems and communication devices allow for an interesting addition to the current view of decision support systems. This concept is what we call "human as a node". With this concept we introduce the ability of human agents to act as members of the network. In the capacity of expert or non-expert, the ability of the network to adapt and adjust to environmental and operational needs in a resilient and dynamic way and identify those human agents who may at that critical time and place represent the key link or hub in the topology. These human actors may then switch from expert to non-expert in a given instance and thus the decision support environment adapts to strengthen the relevant links between nodes.

USSOCOM and NPS TNT MIO

At the individual level, this node is comprised of the human brain. There is no better decision support tool available today. The infrastructure of such models as the TNT MIO with its adaptive mesh topology and advanced command and control toolsets allow for the introduction of the human brain as a node in the network.

The stated goals and objectives of TNT MIO 07-4 (Joint USSOCOM-NPS-LLNL Field Experiment Augmented by OSD/HD MDA Programs), to be conducted in the San Francisco Bay areas in September 2007 are as follows:

> *The objective of this experiment is to continue to evaluate the use of networks, advanced sensors, and collaborative technology for rapid Maritime Interdiction Operations (MIO); specifically, the ability for a Boarding Party to rapidly set up ship-to-ship communications that permit them to search for radiation and explosive sources while maintaining network connectivity with C2 organizations and collaborating with remotely located sensor experts.*
>
> *The particular goal for TNT MIO 07-4 is to take the discovery, constraints analysis, and situational understanding process of network-centric MIO to a new level of fidelity (Bordetsky 2007).*

The Arrival of Network Centric Warfare (NCW)

Network Centric Warfare, or NCW, arrived on the scene in 1996, the result of a paper (and later book) by U.S. Navy Admiral William Owens in which he coined the phrase "system of systems". The objective of this paper was the ability of the United States military to achieve dominance through information superiority. The use of intelligent sensors and advanced command and control methods were the platform to achieve this (Owens 2001).

Many scholars point to 1998 and the reference article in the US Naval Institute Journal *Proceedings* by retired United States Admiral Arthur K. Cebrowski and John Gartska and later expanded in the work by Alberts, Gratska, and Hayes entitled *Network Centric Warfare* as the real beginning of the network-centric movement. This then was the beginning of the movement to gain greater situational awareness and knowledge transfer utilizing the developing communications and information technologies then in development (Cebrowski and Gartska 1998).

Known as “Yoda” or the “the Rabbi”, Andrew Marshall was a long serving RAND analyst (Nuclear Strategist starting in 1949) who many consider the initial proponent and author of “Network Centric Warfare”. His position as the first and only Director of the Pentagon’s Office of New Assessment championed the advent of information technology as the initiator of a “Revolution in Military Affairs (RMA)”. Brought on board during the Nixon administration in 1973, he has been reappointed by every President since. Similar in controversy and following to U.S. Air Force Colonel John Boyd and his “OODA Loop or Observe, Orient, Decide, Act Loop” (see Boyd’s OODA Loop model below) adherents, Andrew Marshall’s followers were known as the “Church of St Andrew”. One of its earliest disciples was U.S. Navy Admiral Arthur K. Cebrowski. Also counted among what is known in defense circles as the “Jedi Knights” is Dr. Andrew F. Krepinevich, West Point graduate, and Harvard PhD currently sitting as the Executive Director of the Center for Strategic and Budgetary Assessments, a private government think-tank (McGray 2003).

This is an important issue in that these men are responsible for the current state of defense transformation and are ushering the era of autonomous robots (armed and unarmed), unmanned aerial vehicles (armed and unarmed), and other advanced networking and communication technologies. In fact, a recent Associated Press article signals the deployment of the first ever Air Force Robot Air Attack Squadron bound for Iraq (Hanley 2007):

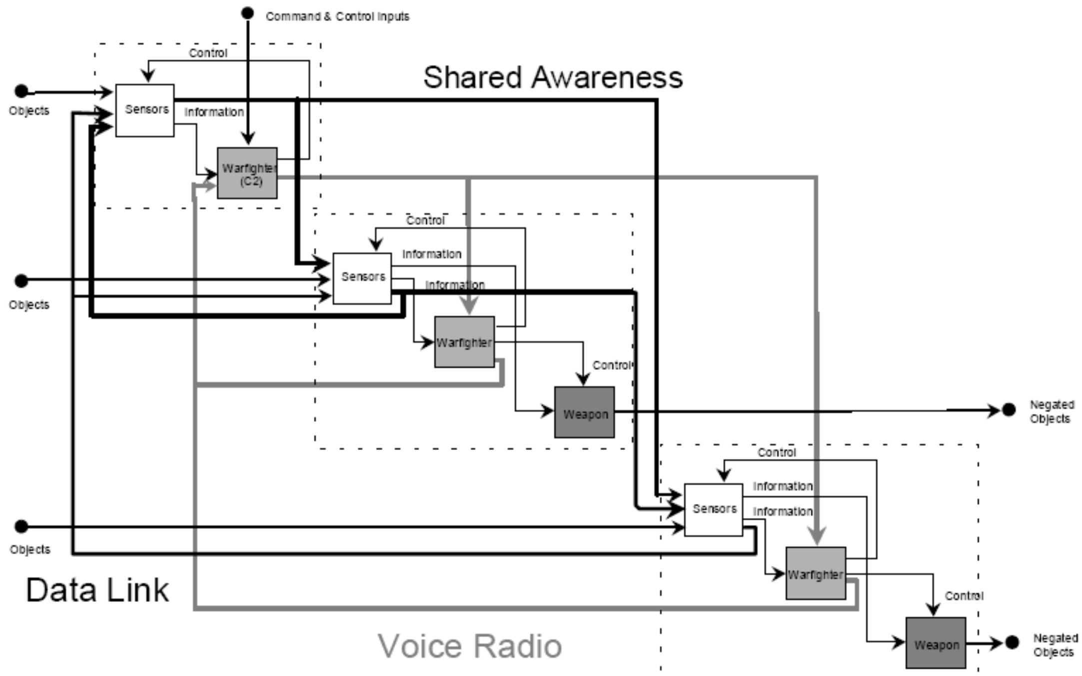
“The airplane is the size of a jet fighter, powered by a turboprop engine, able to fly at 300 mph and reach 50,000 feet. It's outfitted with infrared, laser and radar targeting, and with a ton and a half of guided bombs and missiles.”

“The arrival of these outsized U.S. "hunter-killer" drones, in aviation history's first robot attack squadron, will be a watershed moment even in an Iraq that has seen too many innovative ways to hunt and kill.”

“The Reaper is expected to be flown as the Predator is - by a two-member team of pilot and sensor operator who work at computer control stations and video screens that display what the UAV "sees." Teams at Balad, housed in a hangar beside the runways, perform the takeoffs and landings, and similar teams at Nevada's Creech Air Force Base, linked to the aircraft via satellite, take over for the long hours of overflying the Iraqi landscape.”

What is hidden in this glossy overview of the unmanned aerial attack vehicle is the decision support environment which supports it and enables it to accomplish the mission. As mentioned above, there is a small team of mechanics and maintainers in Balad, Iraq whose job it is to keep the craft flying and serves as launch and recovery specialists. They are networked with the actual pilot and sensor operator located at Creech Air Force

Base, Nevada (just outside of Las Vegas). They in turn are networked to their Operations Center located in Tampa Florida, home of the U.S. Central Command, and finally, they are linked to the specific "actioning agent" on the ground in Iraq-typically U.S. Special Operations Forces, or SOF. This is exactly the type of network centric world envisioned by Marshall, Cebrowski, Alberts, Et al. (See figure below).



Alberts, Gartska, Stein <u>*Network Centric Warfare*</u> *1999*

The key ingredient in all of this technology, however is and always will be the human in the loop or as we call it "human as a node". As stated by Alberts, Gartska, Stein in Network Centric Warfare (1999, 2nd Ed):

> *"Actually, NCW is more about networking than networks. It is about the increased combat power that can be generated by a network-centric force. As we will show, the power of NCW is derived from the effective linking or networking of knowledgeable entities that are geographically or hierarchically dispersed."*

Looking back at the example of the Air Force Robot Squadron, the essential links are those maintained between the human agents handling the UAV and operating it. This is where the decision support environment comes into play. Three recent articles is the Journal of U.S. Special Operations Command "Tip of the Spear" argue exactly for this and serve to showcase the efforts of the Tactical Network Topology Field Experimentation:

1. *"Self-forming, agile networks tying unmanned systems to human activators"* USSOCOM *Tip of the Spear*, January 2007

2. *"Network centric environment created becomes a weapon for the commander"* USSOCOM *Tip of the Spear*, January 2007

"Real time data to command nodes"
3. USSOCOM *Tip of the Spear*, January 2007

Perhaps the most important aspect of these developments is ability to link the various geographically distributed human actors (military personnel, state and federal employees, etc) into this grid of net centricity. We will use the work being done by the Naval Postgraduate School (NPS) and the United States Special Operations Command (USSOCOM) under the auspices of the Tactical Network Topology Field Experiments as a case in point for the need to develop a decision support environment focused along a network centric approach to support knowledge flows. The benefits are impressive and real. As shown in the following diagram by Alberts et al., the pay offs have a tangible benefit to the current mode of thinking (1999).

NCW and "The Edge"

The arrival of the book *Power to the Edge* by Alberts and Hayes in 2003 was a landmark work in that it presented a picture where such advances in technology allowed for rapid exchanges of data and information in such a scale and tempo that the normal military (and business) organization structures could not keep pace. In fact, they called for the recognition of smaller, "edge" organizations, acting in concert with one another, all sharing information and data in real time, with a common goal or objective. There would be no traditional *pushing* of information from central information or knowledge repositories (think Central Intelligence Agency, National Security Agency, Defense Intelligence Agency, and individual Service intelligence agencies). In fact, these edge entities would pull information as needed and share across the entire organization in a truly networked fashion. They would operate and collaborate concurrently (Hayes, Et al. 2003).

IPV6 and the GIG

The deployment of Internet Protocol Version 6 (IPV6) and the Global Information Grid (GIG) are citied two critical examples of the move towards aligning the military establishment within this network centric framework. Critical in that they are seen as true enables of the Network Centric Operations movement (DoD Implementation of NCW 2006). Others include the use of unmanned aerial platforms / vehicles (UAVs) and advanced communications devices such as the Joint Tactical Radio System (JITRS). The common denominator they all share is the ability to enable geographically diverse human agents to maintain an extremely high level of shared awareness and achieve rapid decisive actions at the critical moment in time.

Note
Internet Protocol version 6 (IPv6) quadruples the size of the address field from 32 bits to 128 bits (IPv1-IPv3, and IPv5 reportedly never emerged from testing in the laboratory). IPv6 could theoretically provide each person on the planet with as many as 60 thousand trillion-trillion unique Internet addresses. Theoretically, by switching to IPv6, humanity will never run out of Internet addresses. IPv6 is also believed to be more secure than IPv4 because it offers a feature for encryption at the IP-level.

IPv6 also offers other technical advantages over IPv4. For example, IPv6 makes peer-to-peer communication between individual computers much easier than with IPv4. This will make applications like Internet telephony and next generation multimedia groupware work much more smoothly.

LandWarNet

During a recent speech at the United States Army's LandWarNet (the Army subset of the Global Information Grid) conference in August of 2007, U.S. Army Secretary Peter Geren spoke of the need to stay focused on the arrival of new technologies which would "…seamlessly connect the leader to the soldier on the battlefield — and connect the soldier to the information he or she needs wherever and whenever he or she needs it." In addition, "We are spinning out the first of the [Future Combat Systems] technologies, unattended ground sensors, unmanned aerial vehicles and unmanned ground vehicles," Geren said. "Instead of line-of-sight radio and up-and-down satellite signals, LandWarNet and FCS will give us a three-dimensional mesh of ground, aerial and satellite platforms and nodes, with the soldier on the ground at the center of the effort." Not mentioned during the speech was the critical task of enabling the decision making process to keep pace with this new technology (Geren 2007).

In addition, Marvin Wages, Chief Information Officer (CIO)/G-6 Governance, Acquisition and Chief Knowledge Office (GACKO), for the United States Army, had this to say about the Army's role in network centric operations (Wages 2007):

> *"Our Army is in the midst of a transformational effort to become a net-centric, knowledge based force. In today's environment, modular forces will be integrated with a highly networked backbone with every Soldier serving as an extension of the GIG."*

At the same conference, Dan Garvey, U.S. Army CIO/G-6, spoke in terms of cultural shifts to embrace the technology (Garvey 2007):

> *"The characteristics of operating in the Net-Centric Operating Environment demand that both the culture and technology adapt so that rapid and ubiquitous access to relevant information becomes a distinct strategic and tactical advantage. This challenge is not only merely the acquisition of more systems or connections, but involves a cultural shift that allows relevant information to be*

readily accessible where it is needed, without the impediments of organizational barriers or excess infrastructure."

The Fog of War

Carl von Clausewitz wrote *Vom Kriege* (on War) between 1816 and 1830, based on his experiences during the French Revolution and the Napoleonic Wars. Published posthumously in 1832 by his wife, it introduced the world to the concept of "the fog of war". Included in this treatise is the famous phrase: "War is the realm of uncertainty; three quarters of the factors on which action is based are wrapped in a fog of greater or lesser uncertainty." The development of this decision support environment is the next step in reducing the fog of war and moving towards total situational awareness and knowledge transfer. As stated by Alberts, Et al. in Network Centric Warfare (1999):

> *"The fact that warfare will always be characterized by fog, friction, complexity, and irrationality circumscribes but does not negate the benefits that network-centric operations can provide to the forces in terms of improved battlespace awareness and access to distributed assets. While predicting human and organizational behavior will remain well beyond the state of the art, having a better near real-time picture of what is happening (in situations where this is possible from observing things that move, emit, etc.) certainly reduces uncertainty in a meaningful way.*

The traditional role of the decision support system is to enable the decision maker in a fairly static and rigid hierarchical organization. The role of "who decides what" is largely a function of a higher headquarters in any typical organizational structure (Simon 1947). What we are proposing is a new form of decision support system: *the decision support environment (DSE)*-whereby a given network adapts to strengthen those links between experts and non-experts (human and / or machine) as the environment and operational necessity requires. Typically this will present itself in crisis management and military operations.

Traditional Decision Support Systems

The current view of the computer-based decision support system is typically one of five themes (Powers 2007):

1. Communications Driven-as exemplified by Microsoft Groove and other such types of collaborative software, enabling various actors to engage in shared tasking.
2. Data Driven-as the name implies, this is data driven and relies on access to relevant databases to support decision making (Marakas 2003)
3. Model Driven-using models to leverage existing processes and simplify decision making.
4. Document Driven-using unstructured documents (usually in the form of electronic documentation) to facilitate decision making.

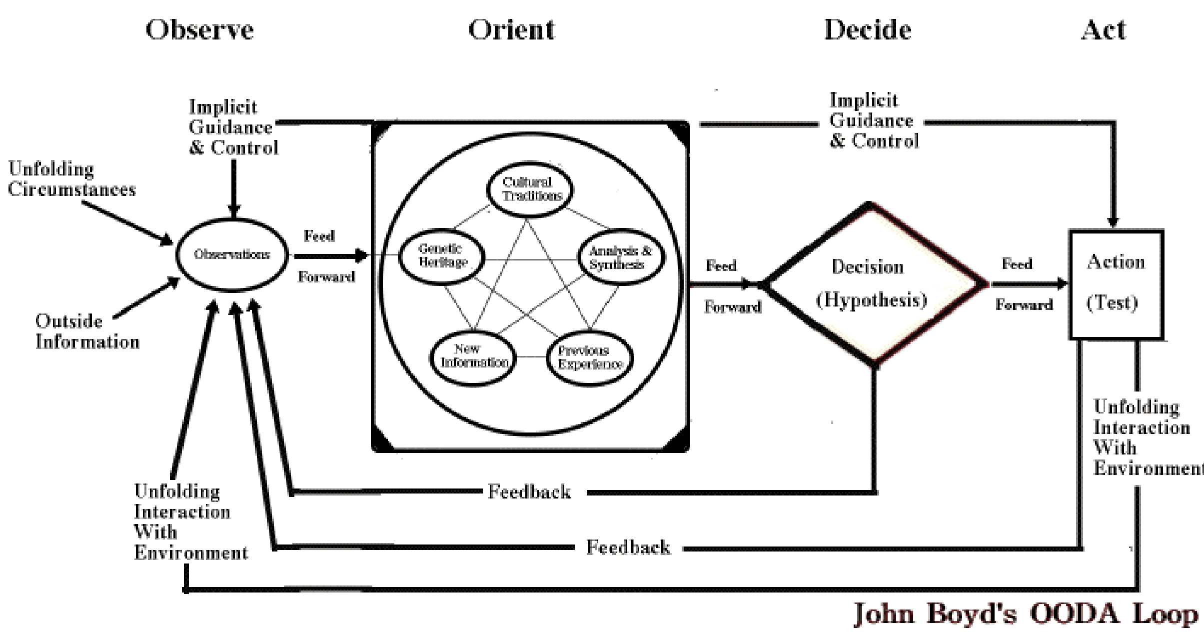
5. Knowledge Driven-knowledge based and dependent on access to specific and supporting knowledge experts (human and machine) to facilitate decision making.

These themes have largely remained constant for the past 50 years. While many in the field argue over the specifics of the exact boundaries of the decision support field, these themes have emerged as convenient buckets in which to bin the various categories of toolsets used to assist the human actor in the process of processing ever increasing data and information flows.

Decision Making Models

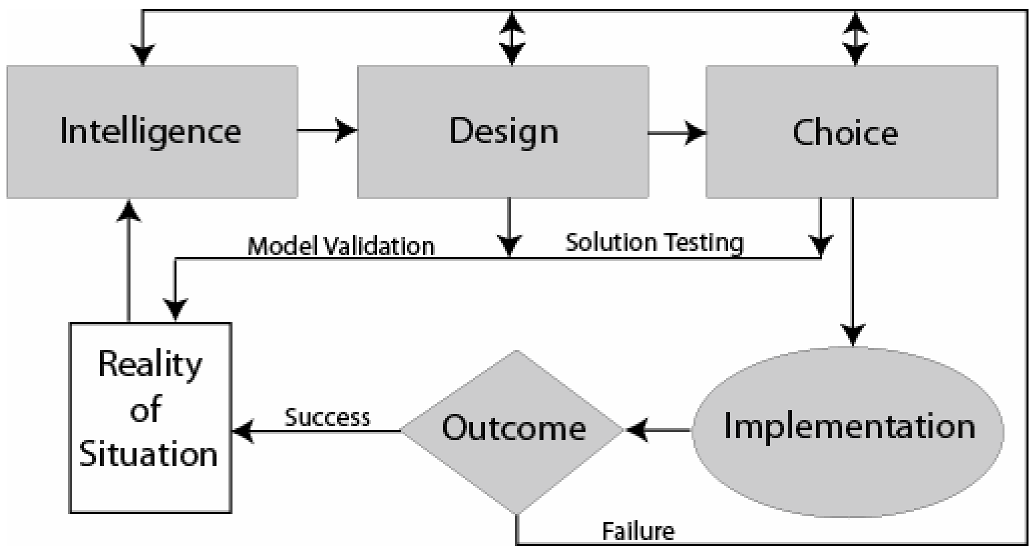
The current field of decision support systems can then be grouped as one of three main decision making models:

1. John Boyd’s four phase and feedback dependent Observe, Orient, Decide, Act loop (also known as OODA Loop) (Coram 2002) in which the aim of the decision support model is to get an advantage over an opponent by “getting inside his decision cycle”. First applied to Air Force aerial combat, it has since moved to the business realm. Of particular note in the diagram below is the fact that this loop is actually a continually updating series of interacting loops-hence the reliance on continuous feedback.



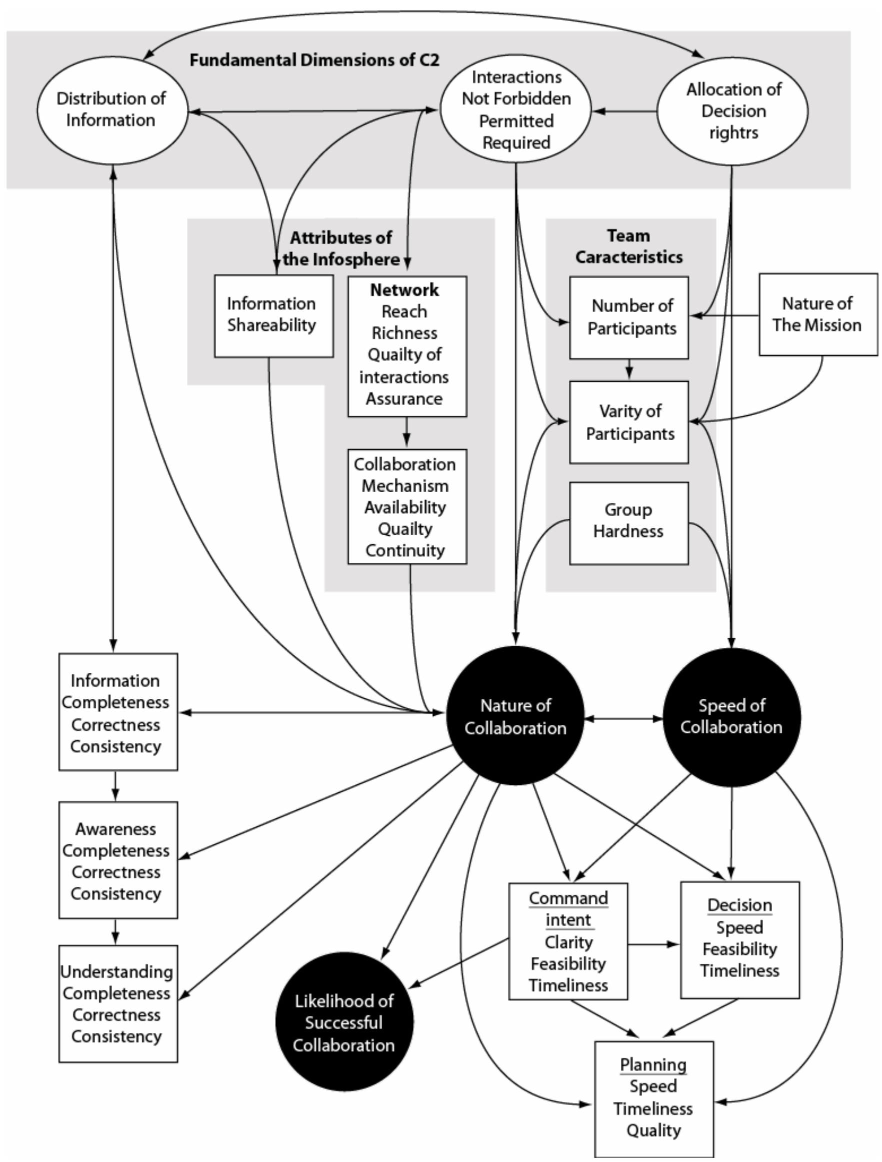
Redrawn version of John Boyd's OODA loop produced by Patrick Edwin Moran.

2. Herb Simon's three phase problem solving model (Simon 1979) which is hierarchical in nature and designed as such for its robustness. In effect, it is a series of events which begins by identifying all relevant alternatives to the task at hand, development of consequences to align with the alternatives, and finally, a comparison based on accuracy and efficiency.



Simon's Problem Solving Model

3. The network centric themed Collaboration Significant Influences model of Alberts and Hayes-a much more evolved and detailed model than the previous two. (2006).



Alberts and Hayes Collaboration Significant Influences Model

It is important to note the significance to which Alberts and Hayes place on the value of information. Also, one can note how independent of hierarchy the Alberts and Hayes model is. In fact, this may not go far enough as it is knowledge which enables action and therefore should be the focus of a decision support framework (Nissen, 2006).

Groupware and Group Support Systems

Alternatively, there is another area of decision support systems which deals with a concept known as groupware-that is, the collaborative sharing of information in a synchronous and asynchronous manner across distributed environments. Of special interests is the field of Computer-Supported Cooperative Work (CSCW). This field is not without its own significant challenges (Bordetsky, Mark 2000). Perhaps the most important challenge as it pertains to the TNT MIO is the ability of groupware to enable a sense of shared awareness in real or near real-time (Bordetsky, Mark 2000). Another issue is the ability to transfer knowledge in a meaningful way that is understood by all members of the team. It is these challenges which lend caution to our inclusion of this type of decision support system to the TNT MIO architecture.

Briggs, Nunamaker, and Sprague have explored the idea of group support systems or GSS even further. Defined as "a suite of software tools, each of which focuses team efforts in some unique way" (Briggs, Et al 2000), many have stated that the field of GSS research is dead. However, the state of the art in GSS research does not presently support the needs of the tactical or crisis management team. That said, this field deserves more in depth review and research and holds promise for the future of collaborative team work in a virtual environment.

DSS Characteristics

Accordingly, there are any number of traits that a given decision support system should have. According to Turban et al. the ideal characteristics of a decision support system are as follows (1997):

1. Support for decision makers in semi structured and unstructured problems.
2. Support managers at all levels.
3. Support individuals and groups.
4. Support for interdependent or sequential decisions.
5. Support intelligence, design, choice, and implementation.
6. Support variety of decision processes and styles.
7. DSS should be adaptable and flexible.
8. DSS should be interactive and provide ease of use.
9. Effectiveness balanced with efficiency (benefit must exceed cost).
10. Complete control by decision-makers.
11. Ease of development by (modification to suit needs and changing environment) end users.
12. Support modeling and analysis.
13. Data access.
14. Standalone, integration and Web-based.

The conventional decision support system has existed largely unchanged for the past 50 years, and we argue that even with the addition of the computer as an enabler, the DSS as it has evolved has now arrived at a point in time which calls for a revolution in terms of capability. This revolution is the direct result of incredible benefits of modern networking capabilities and the current conceptual work done in the network centric operations field.

The Experimental Design

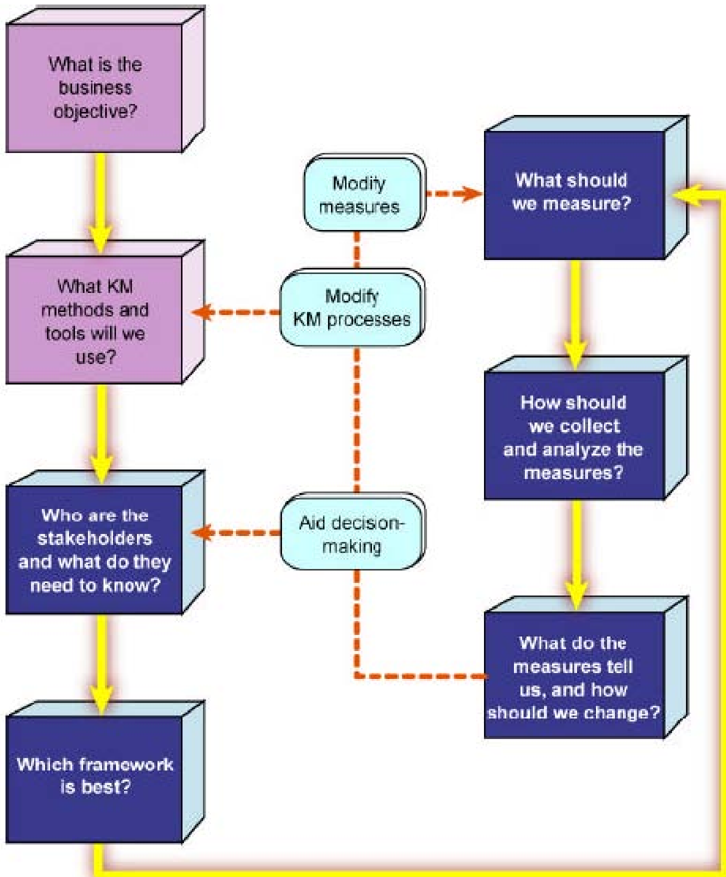
Perhaps the most challenging aspect of the arrival of the decision support environment and the concept of dynamic knowledge mesh flows is the question of analytical measures of effectiveness (MOE). That is, how does one show value gained for implementation of the necessary networking and collaborative schema to support this on a global scale.

Early attempts at giving measure to the relative value of information were born out by such authors as Nyquist (1924) and Hartely (1928). Also of note was the work of statistician Fisher in 1925. However, we look to the seminal work done by Claude Shannon in 1948 and his reference paper, "*A Mathematical Theory of Communications*" for the broadest and most relevant foundation of information theory. It is here that we start in our design of experimentation.

The RAND Arroyo Center published a book in 2001 entitled *Measures of Effectiveness for the Information Age-Army*. In it, the authors describe information as having two distinct characteristics: *value* and *quality*. They tie this concept in with the notion that knowledge is actually information that has relevance and is therefore deemed *valuable* (2001). It is this framework with which we will use to capture our data.

Design Considerations and Parameters

One of the most important considerations when trying to measure knowledge transfer is figuring out exactly what it is you are trying to measure. Our initial step is to identify those variables for which we are interested in and really amount to the attributes of the desired measurements. As outlined in *Code of Best Practice for Experimentation*, metrics and measures of effectiveness should always start with a grouping or list of the desired dependent variables (Alberts 2005). Developed by the United States Navy, he model below is the thought process used for deriving our measurement metrics.



The KM Measurement Process, Department of the Navy 2001

As stated in the *U.S. Navy Metrics Guide for Knowledge Management Initiatives* (2001), the most important consideration is whether or not the metric tells us if the knowledge is being shared and used. Another consideration is whether to pursue qualitative or quantitative measurements. We use this then as a guide to the development of our dependent and independent variable set as seen below:

Design Variables

Variable **Unit of Measure**
Output Measures *Counts, estimates, surveys*
Outcome Measures *Hard to define (intangibles) Track Changes / Differences*
Level of Knowledge *Qualitative Assessment (Individual, Team, Organization)*
-- --
System Measures

Quantitative (Hard data) #

Number of Nodes-Human
Quantity #

Number of Nodes-Machine
Quantity #

Distance
Kilometers

Size of the Network
Quantity # (Degree of scale between expert nodes)

Network Link Density
Quantity #

Decision Time (Speed of Reaction)
Minutes

Method of Transfer
Descriptor (VHF, UHF, Voice, IP, VOIP, etc

Degree of Separation between Nodes
Quantity #

Type of knowledge
Tacit or Implicit

Operational Roles
Qualitative data (Boarding Party OIC, AOIC, etc…)

Relationships

The relationships developed between the variables listed above will serve to help identify the strengths and weakness of the three models of decision making and it is hoped that the outcome of the experimentation will help showcase the merits of our new decision support environment based on knowledge flows. Some of these relationships will be "discovered" during the course of the experimentation while others present themselves readily-an example being the number of nodes and the distance between "actioner" and command unit or node.

Pareto Set of Criteria

There are many advantages to moving towards a network centric decision support environment (dynamic knowledge flow mesh) but perhaps the greatest indicator of its usefulness is the level of effectiveness. The Pareto Set of criteria lends itself to this study as we in effect, attempt to "optimize" the transfer of knowledge across the network and make the decision support environment as effective and efficient as it can be given its ad-hoc nature. Some examples would be a reduction in response time or an increaser in the amount of knowledge flow across a given topology within the decision support environment.

The result of this experiment is the optimization of the decision support environment in a given operational condition-be it military, crisis management, or disaster relief.

Building the Experiment

The primary goal of the experimentation phase is the successful discovery of the knowledge flows within the adapting network topology and to ultimately identify the best decision support model with which to support knowledge flows. We begin with three phases of experimentation:

1. Pre-experimentation (what we know, what we think, and what we are going to do).

2. Conduct the experiment (the empirical data and observations).

3. Post-experimentation (revised model, lessons learned, and data for future experimentation).

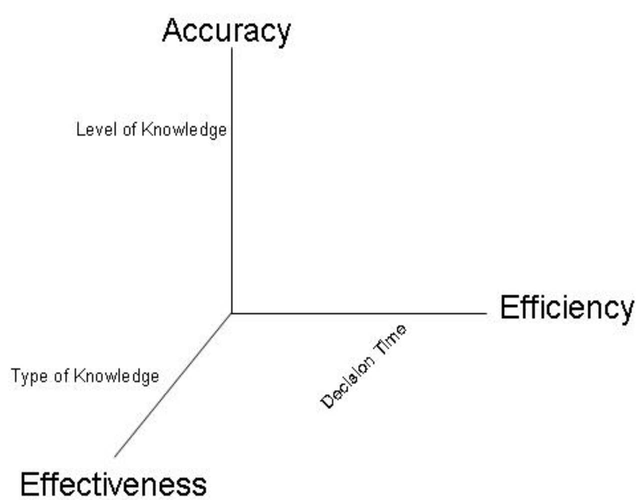
The bulk of our effort will be placed in the "pre-experimentation" phase in which we codify that information and knowledge we have, develop a series of assumptions and/or hypothesis, and design the experiment (Alberts, Et al. 2005). Our goal is the identification of knowledge flows and the adaptability of the network to enable such flows in a timely and decisive manner. By establishing a well-bounded experimentation routine and setup in the pre-experimentation phase in the pursuit of what is already known, we can identify any issues early on which may hamper our ability to later move the experimentation into unknown waters and enter the discovery mode of experimentation. In terms of resource allocation, this can save us huge amounts of time and funds later on.

Scenario

Interesting work has been done recently in this field. In particular, the work of Hutchins, Bordetsky, Kendall and Bourakov and the *Empirical Assessment of Team Collaboration* (2006) is well suited to our task. In it, the authors utilize the TNT MIO as the basis for team collaboration using off the shelf collaboration tools sets such as Microsoft Groove. In a similar vein, we propose setting up a scenario-based sense making utilizing the TNT MIO supporting architecture.

We posit that three separate yet identical tactical scenarios be run, each with the goal of getting the best and most current knowledge flow to the primary actor. In this case, the primary actor is the boarding party officer, yet we understand that due to the unpredictable nature of tactical situations, the ability of another member to gain a position of knowledge dominance needs to be looked at and monitored. This is in a sense, the power of network centric operations and particularly relevant given today's networking and collaboration tools.

Using a Lickert scale model based on a rating of 1-10, each scenario would be run in an identical manner and the criteria listed above assessed. Of course, certain relevance would be placed on knowledge and its use as we see this as the foundation of the new decision support system. The standard to be measured against would encompass accuracy, efficiency, and effectiveness. This raw data can then be analyzed to give a statistical grounding in the development of our new model (Post-experimentation phase). In effect, what we are looking for is a standard of fitness based on the scenario in which the goal is the identification of key attributes which support the need for a new network centric model. The resultant data can then be mapped to a multidimensional visualization in order to tease out the requisite characteristics for each model as it applies to each scenario. See figure below for an output example.



Multidimensional Visualization Matrix of Output

Hypothesis Testing

Sample hypothesis for testing utilize the methodology contained in Alberts and Hayes *Code of Best Practice for Experimentation* (2005) include:

-If we reduce the amount of non-critical nodes (machine and human) between command node and actioner, then the reaction time will decrease.

-If we increase the amount of information access to the MIO boarding party, then knowledge will increase.

-If we reduce the amount of time needed to link critical knowledge experts, then the reaction time of the entire boarding party will increase.

Experimental Baseline

The proposed experiment baseline is to be the TNT MIO baseline stated earlier at the beginning of this paper:

The stated goals and objectives of TNT MIO 07-4 (Joint USSOCOM-NPS-LLNL Field Experiment Augmented by OSD/HD MDA Programs), to be conducted in the San Francisco Bay areas in September 2007 are as follows:

> *The objective of this experiment is to continue to evaluate the use of networks, advanced sensors, and collaborative technology for rapid Maritime Interdiction Operations (MIO); specifically, the ability for a Boarding Party to rapidly set up ship-to-ship communications that permit them to search for radiation and explosive sources while maintaining network connectivity with C2 organizations and collaborating with remotely located sensor experts.*
>
> *The particular goal for TNT MIO 07-4 is to take the discovery, constraints analysis, and situational understanding process of network-centric MIO to a new level of fidelity (Bordetsky 2007).*

Conclusion

This paper has shown that there exists a gap between the current thought regarding decision support systems and the tactical application of modern communication devices, networking capability, sensor saturation, and maturation of mobile technologies. We have provided a framework and measures of effectiveness for the testing of future implementations of hybrid decision support environments with the ability to sense, react, and configure a mesh network topology to facilitate the transfer of knowledge to enable action.

One area that we believe to have special importance is the nature of the knowledge flow as it pertains to the boarding party and its relationship with the C2 nodes spread out across geographical boundaries. The study of this ecology presents a perfect opportunity to identify the use of links to channel this flow across the various human and machine expert systems in addition to the primary "actioners". The results gleaned from the controlled TNT MIO Field Experiments should serve to better inform the current operational issues facing such complex endeavors as UAV operations as they currently posture and the anticipated operational debut of the combat UAV or CUAVs currently in theatre. We intend to use the three scenarios as a chance to "map" these knowledge flows. This also has the advantage of identifying or 'pointing" to those individuals who maintain tacit knowledge repositories in addition to those explicit knowledge clumps that are to be expected.

The network architecture already exists in the form of the TNT MIO Field Experimentation and it is now time to develop the model for knowledge transfer in a dynamic mesh topology to support the ad hoc nature of tactical and crisis response management.

Implications for Future Experimentation: Knowledge Mapping and GSS

Finally, there is a valid need to look into the work of Briggs and Nunamaker at the University of Arizona. Specifically, the field of Group Support Systems and it's relevance in the asynchronous virtual world of tactical operations and crisis management. It is our belief that this area is rich in opportunity for current military operations. It is believed that once the technology matures to a point where it can support graphical intensive knowledge exchange in near to real time, that this may produce some interesting enables to support our work.

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NAVAL
POSTGRADUATE
SCHOOL

Knowledge Flow Mesh and its Dynamics: A Decision Support Environment

13th ICCRTS: C2 Architectures Track

Major Jack L. Koons III, USA

Motivation

- Personal Experience
  - *Desert Storm* and *The Long War*

- Advances in Modern Communications and Networking Ability
- Sensor Saturation &Maturation of Mobile Technology
- USSOCOM and NPS Partnership
- Arrival of Network Centric Warfare
  - Post Desert Storm of 1991
    - Air Plan Briefs to Airborne Downloads
  - FCS, UAVs, and UCAVs
    - *The Reaper*

DSS to DSE

In today's dynamic, information rich, and high operational tempo, the need for a robust, resilient, and adaptable decision support environment is greater than ever before.

Of particular emphasis here is the context of a "network-centric" approach or lens. Existing literature focuses on the development of the decision support system as a "system" under the control of one or more decision makers (Marakas 2003)).

Added to this is the need for a clearly defined problem statement which then, in turn, relates to a particular form of decision support system.

The form of DSS is based upon the problem structure, the type of outcome needed, and finally, the type of overhead or control required.

DSS Gap

Earlier attempts to bind the characteristics of robust decision support systems with the requisite ability to serve as a knowledge flow enablers to include the ability to adapt and mesh with existing networks and systems have come up short.

Articles and conference papers by such leading edge researchers as Bordetsky, Hayes-Roth and Vega, Clements, and Thompson have attempted to either bin the particular DSS as either hybrid (Vega, et al. 2007) or place the functionality onto an architectural structure (Bordetsky, Hayes-Roth 2007).

DSS Gap: GSS Update

Briggs, Nunamaker, Sprague
The University of Arizona
Center for the Management of Information

Group Support Systems: Defined as "a suite of software tools, each of which focuses team efforts in some unique way" (Briggs, Et al 2000), many have stated that the field of GSS research is dead.

However, ***the state of the art in GSS research does not presently support the needs of the tactical or crisis management team***. That said, this field deserves more in depth review and research and holds promise for the future of collaborative team work in a virtual environment.

Research Question

- Which DSS is best suited for today's rapidly adapting and evolving network centric tactical situations?
- In this paper we introduce the concept of *Knowledge Flow Mesh Dynamics* within a decision support environment, which we argue is the logical heir to a new type of decision support system as seen through the network centric lens.

Prior and Ongoing Research

- *“Leverage experiments that identify key gaps and deficiencies resulting from applications of advanced technology, unmanned systems, and net centric applications”*

- USSOCOM and NPS Partnership
  - Cooperative Field Experimentation
  - CENETIX Lab
  - MIO
  - UAS
  - Distributed Ops
  - Enhanced Battlefield Medical SA

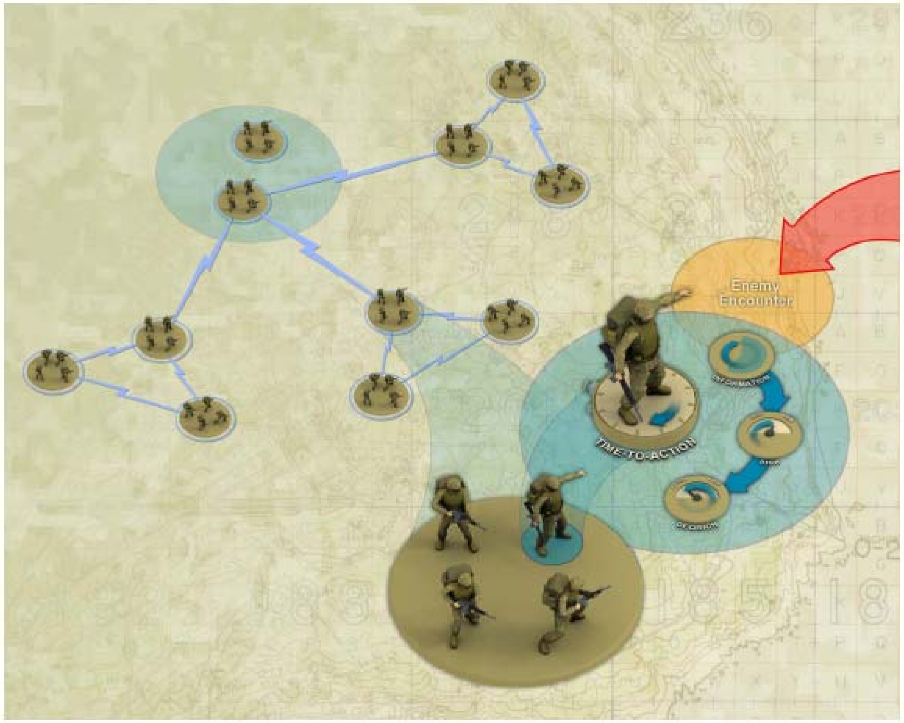
Decision Support Environment

- Identification of Knowledge Nodes
  - Knowledge Flows (Nissen, 2006)
  - Human or Machine
  - Dynamic (Right Expert-Right Time)
    - Bandwidth Optimization
    - Think IP Packets / Knowledge Packets & Nodes

We are trying to enable the dynamic transfer of knowledge across as yet to be determined network topologies and architectures at the right time and location.

Adaptive Knowledge Mesh Topology

- Information
  - Static
- Knowledge
  - Dynamic
  - Shelf Life
  - TTL
- Actor
  - Decision Maker
  - Shooter
  - New Information Created



The Proliferation of Decisionmakers

Building the Experiment

The primary goal of the experimentation phase is the successful discovery of the knowledge flows within the adapting network topology and to ultimately identify the best decision support model with which to support knowledge flows. We begin with three phases of experimentation:

1. Pre-experimentation (what we know, what we think, and what we are going to do).

2. Conduct the experiment (the empirical data and observations).

3. Post-experimentation (revised model, lessons learned, and data for future experimentation).

The bulk of our effort will be placed in the "pre-experimentation" phase in which we codify that information and knowledge we have, develop a series of assumptions and/or hypothesis, and design the experiment

Hypothesis Testing

Sample hypothesis for testing utilize the methodology contained in Alberts and Hayes *Code of Best Practice for Experimentation* (2005) include:

-If we reduce the amount of non-critical nodes (machine and human) between command node and actioner, then the reaction time will decrease.

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The proposed experiment baseline is to be the TNT MIO baseline stated earlier at the beginning of this paper:

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This is in a sense, the power of network centric operations and particularly relevant given today's networking and collaboration tools.

Data Collection

Using a Lickert scale model based on a rating of 1-10, each scenario would be run in an identical manner and the criteria listed above assessed.

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This raw data can then be analyzed to give a statistical grounding in the development of our new model (Post-experimentation phase).

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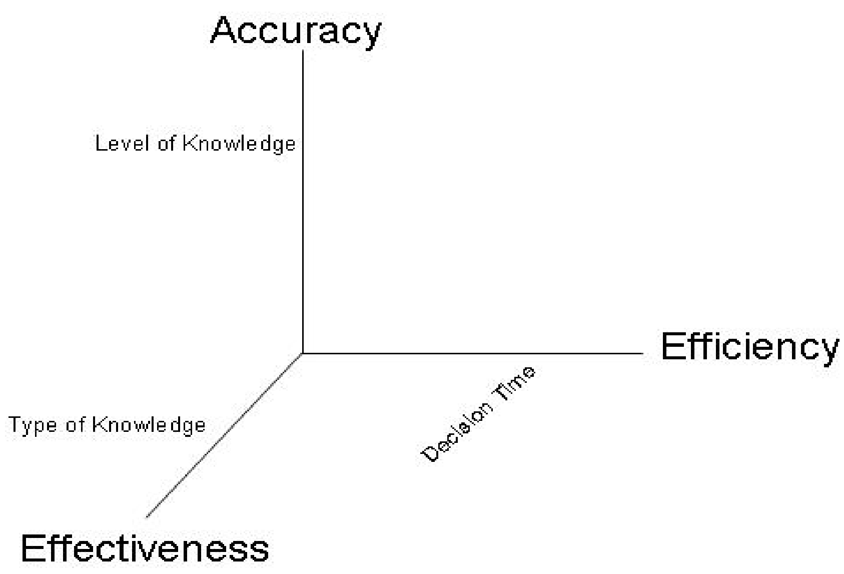
Multidimensional Visualization Matrix of Outputs



Limitations

- The Network is Impersonal
  - Information and Data are Easy
  - Transfer Bits and Error Checking
- Knowledge Transfer is Personal
  - Tacit vice Explicit
  - Hardest to Transfer (Nissen, 2006)

Implications for Future Research

One area that we believe to have special importance is the nature of the knowledge flow as it pertains to the boarding party and its relationship with the C2 nodes spread out across geographical boundaries.

The study of this ecology presents a perfect opportunity to identify the use of links to channel this flow across the various human and machine expert systems in addition to the primary “actioners”.

We intend to use the three scenarios as a chance to “map” these knowledge flows. This also has the advantage of identifying or ‘pointing” to those individuals who maintain tacit knowledge repositories in addition to those explicit knowledge clumps that are to be expected.

Further Research

Finally, there is a valid need to look into the work of Briggs and Nunamaker at the University of Arizona. Specifically, the field of **Group Support Systems** and it's relevance in the asynchronous virtual world of tactical operations and crisis management.

It is believed that once the technology matures to a point where it can support graphical intensive knowledge exchange in near to real time, that this may produce some interesting enables to support our work.

Questions and Comments