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Deployable Network Operations Center (DNOC) a collaborative technology infostructure designed to support tactical sensor-decision maker network operations

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THESIS

DNOC: A COLLABORATIVE TECHNOLOGY INFOSTRUCTURE DESIGNED TO SUPPORT TACTICAL SENSOR-DECISION MAKER NETWORK OPERATIONS

by

Shawn E. Johnson
June 2005

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The coordination and collaboration of information has never before been more important to the success of tactical missions. Hybrid wireless-mesh networks have the capability to put critical information at the fingertips of the operator, enabling tactical units to successfully carry out their missions. The increasing use of expeditionary and special operations forces operating in ad hoc, dynamic, and tactical environments poses a need for an adaptable, flexible, and responsive Deployable Network Operations Center (DNOC) to support their efforts. Whether co-located or virtual, the DNOC must supply tactical units with the right information, at the right time, and in the right format. The DNOC must also serve as a rapid, reliable, and secure communications network platform so that forces can collaborate in a manner which builds quality interactions and trust. This thesis effort consisted of designing, building, and implementing a DNOC to support Naval Postgraduate School's Tactical Sensor-Decision Making Network (TSDN) field experiments. Baseline operating processes were explored and recommendations for life-cycle maintenance and future upgrades are made.

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Submitted in partial fulfillment of the
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ABSTRACT

The coordination and collaboration of information has never before been more important to the success of tactical missions. Hybrid wireless-mesh networks have the capability to put critical information at the fingertips of the operator, enabling tactical units to successfully carry out their missions. The increasing use of expeditionary and special operations forces operating in ad hoc, dynamic, and tactical environments poses a need for an adaptable, flexible, and responsive Deployable Network Operations Center (DNOC) to support their efforts. Whether co-located or virtual, the DNOC must supply tactical units with the right information, at the right time, and in the right format. The DNOC must also serve as a rapid, reliable, and secure communications network platform so that forces can collaborate in a manner which builds quality interactions and trust. This thesis effort consisted of designing, building, and implementing a DNOC to support Naval Postgraduate School’s Tactical Sensor-Decision Making Network (TSDN) field experiments. Baseline operating processes were explored and recommendations for life-cycle maintenance and future upgrades are made.

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ACRONYMS AND ABBREVIATIONS

AAR	After Action Report
AGV	Autonomous Ground Vehicle
AI	Artificial Intelligence
AOR	Area of Responsibility
AUV	Autonomous Underwater Vehicle
AV	Audio/Video
AVMM	Audio Video Multimedia
BP	Business Processes
BR	Business Rules
CDTEMS	Center for Defense Technology and Education for the Military Services
CIRPAS	Center for Interdisciplinary Remotely Piloted Aircraft Studies
CLE	Collaborative Learning Environment
CoS	Class of Service
CONOPS	Concept of Operations
COP	Common Operational Picture
COTS	Commercial-off-the-Shelf
CROP	Common Relevant Operational Picture
CROWN	Common Relevant Operational Wall of Networking
CTI	Collaborative Technology Infostructure
DNOC	Deployable Network Operations Center
DoD	Department of Defense
DSS	Decision Support System

DVI	Digital Visual Interface
EM	Emerging Technology
ES	Expert System
FOV	Field of View
GCCS	Global Command and Control System
GIGA	Global Information Grid Applications
GIG-BE	Global Information Grid – Bandwidth Extension
GUI	Graphical User Interface
GWOT	Global War on Terrorism
HSI	Human Systems Interface
ICT	Information and Communication Technology
IEDs	Improvised Explosive Devices
IM	Information Management
IS	Informational Structure
ISR	Intelligence Surveillance Reconnaissance
IST	Information Systems Technology
IO	Information Operations
IP	Internet Protocol
IT	Innovative Technology
IW	Information Warfare
KM	Knowledge Management
LCS	Littoral Combat Ship

LRV	Light Reconnaissance Vehicle
MIB	Management Information Base
MilSpec	Military Specification
NCES	Network Centric Enterprise Services
NCO	Network-Centric Operations
NCW	Network-Centric Warfare
NOC	Network Operations Center
NPS	Naval Postgraduate School
OFDM	Orthogonal Frequency Division Multiplexing
OFT	Office of Force Transformation
OS	Organizational Structure
OSD	Office of the Secretary of Defense
QoS	Quality of service
RGB	Red Green Blue
SA	Situational Awareness or Shared Awareness
SU	Situational Understanding
SNMP	Simple Network Management Protocol
SOCOM	Special Operations Command
SOF	Special Operations Forces
SOP	Standard Operating Procedure
TAC-SAT	Tactical Satellite (Office of Force Transformation)
TT&P	Tactics, Techniques and Procedures
TOC	Tactical Operations Center

TNT	Tactical Network Topology
TSDN	Tactical Sensor-Decision Maker Network
UAV	Unmanned Arial Vehicle
UCMJ	Uniform Code of Military Justice
UGV	Unmanned Ground Vehicle
UPS	Uninterruptible Power Supply
VIRT	Valued Information at the Right Time
VLE	Virtual Learning Environment
WBS	Work Breakdown Structure

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EXECUTIVE SUMMARY

Researchers are seeking ways to leverage information technology to gain an advantage in constrained and restricted urban environments. The increasing use of expeditionary and special operations forces operating in ad hoc, dynamic, and tactical environments poses a need for an adaptable, flexible and robust Deployable Network Operations Center (DNOC) to support these efforts. Whether face-to-face or virtual, a network centric operation (NCO) team must have business processes in place that infuse the right information, at the right time, and in the right format; they must also be able to collaborate based on the interpretation of this information in a manner which builds shared situational understanding and trust. Effective coordination and cooperation across, within, and among NCO forces are critical to the overall success of the tactical mission.

Naval Postgraduate School's applied research – Tactical Network Topology (TNT) testbed is well-suited to study and support the ad hoc nature of expeditionary and special operations. TNT is encompassed in a broader concept of Tactical Sensor-Decision Maker Network (TSDN) campaign of experimentation. TNT is both a platform for NCO field experiments and the subject of those experiments. TNT's primary research objectives are: 1) to demonstrate tactical situational and network awareness through improving information management, and 2) to enhance the geo-distributed tactical warfighters' ability to self-synchronize collaboratively over a robust network topology. For all practical senses the users involved participate and mesh over an experimental hybrid testbed of wireless technologies (links) and manned/unmanned mobile platforms (nodes). TNT strives to increase shared situational understanding and quality interactions by supporting research concerning the communications-negotiations-coordination processes that result from tactical operators networking across and within a wireless network of sensors and disparate sources of information platforms.

The TSDN operational framework, that guided the DNOC's design, models four specific, yet mesh-like functions that leverage value-added information: people, processes, information, and systems technology. TSDN is defined as a bottom-up functional aggregation architecture that models interdependent relationships between humans and technology during the exchange of ideas, negotiation of information

services, and collaborative problem solving. This can be contrasted with traditional top-down hierarchical command and control structures.

Reliability and availability alone are not enough to ensure that the tactical operator obtains shared situational awareness. The organizational structures, informational structures, operational structures, and the social-technical interfaces (the way technology is implemented in the social environment) must all be integrated so that the operator gets the right information, in the right format, and at the right time. This point of entry leads to the emerging concept of the Deployable Network Operations Center (DNOC).

This thesis effort consisted of designing, building, and implementing a DNOC infrastructure along with proposing a baseline infostructure that supports knowledge practitioners' organizational learning. The author's treatise is that the DNOC ultimately becomes a unique plug-and-play environment that supports communication-negotiation-coordination processes that occur across adaptable, flexible and mission-responsive ad hoc networks of tactical units. It is the author's vision that the DNOC supports the integration and deployment of mobile manned/unmanned platforms so that researchers can explore and discover different models of baseline operating processes that are inherent to net-centric operations. Given these provisions along with accelerating tactical battle rhythms within a sensor-effector (shooter) network, it is more than likely that future TSDN research will successfully enhance coordination and co-operation mechanisms that shape the meaning of a "robustly networked force."

I. INTRODUCTION

A. BACKGROUND

NPS’s applied research, Tactical Network Topology (TNT), is a research testbed that is used to evaluate the effects of emerging technologies that may very well influence, shape, and transform the nature of future tactical net-centric operations. TNT is encompassed in a broader concept of Tactical Sensor-Decision Maker Network (TSDN) campaign of experimentation. The eventual impact of TSDN research will redefine how specific innovations in mobile sensor and wireless networking technologies are discovered and demonstrated in terms of their potential to improve tactical mission performance capabilities. In future battlefield operations, autonomous and semi-autonomous agents such as Unmanned Airborne Vehicles (UAVs), Autonomous Underwater Vehicles (AUVs), and Autonomous Ground Vehicles (AGVs) will need to organize in clusters (teams) in order to launch complex tactical operations (Gerla, p.7, 2005). The TSDN campaign is well-suited to study and support the ad hoc and expeditionary nature of complex tactical operations. TNT’s hybrid wireless-mesh testbed, as depicted in Figure 1, provides a platform for Network Centric Operations (NCO) field experiments and is also the subject of many of those experiments.

TSDN's primary research objectives are: 1) to pursue vigorous efforts aimed at the conceptualization and hypothesis testing of new wireless-sensor performance capabilities that allow the leveraging of concepts inherent in NCO; and 2) to focus attention on discovering interactions among sensors and decision makers that are necessary to generate synergistic and synchronized effects. TSDN strives to demonstrate shared perceptual awareness and interdependent confidence by supporting communications, negotiations, and coordination amongst tactical agents operating across and within a wireless mesh network of mobile support platforms, sensors, and effectors (shooters).

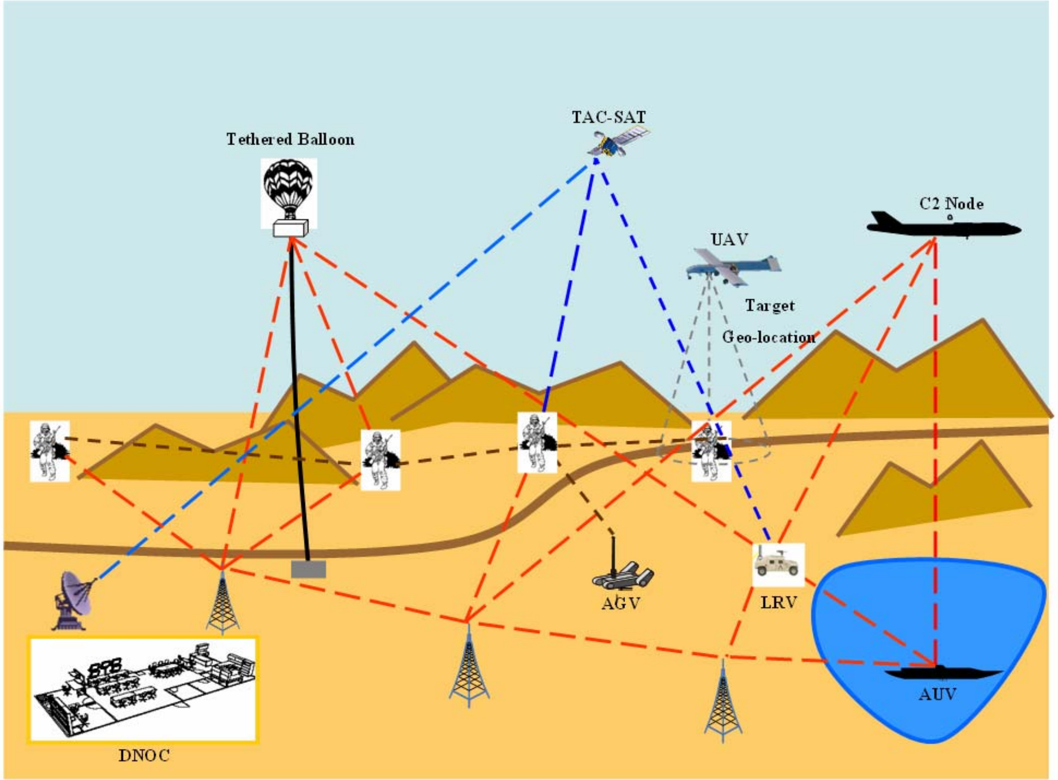

Figure 1. TNT Hybrid Wireless-Mesh Testbed

The TNT testbed and the TSDN campaign of experimentation provides analytical background and hands-on experience with information management systems and information management infrastructures that integrate into the Global Information Grid Bandwidth Expansion (GIG-BE) architecture. TSDN targets support to manned and unmanned sensors, Network Centric Enterprise Services (NCES) as well as terrestrial, satellite, and mobile wireless network operation centers. Researchers and students look at fixed, vehicle-based, and man-portable network operations center solutions. Additionally, a significant effort is placed on research that supports the management challenges associated with the deployment of adaptive, self-forming, mesh networks comprised of unmanned vehicles, sensors, and geographically dispersed operators. The TNT experiments and an emerging TSDN campaign is managed by a distinguished team of principal investigators that range from a field experiment coordinator and network systems architect to technology researchers in areas such as UAVs, AUVs, AGVs, sensors, smart antennas, and human systems integration.

The TSDN investigators routinely conduct research in the following areas:

- Self forming, self organizing, and self healing wireless networks
- Protocols and technologies for mesh networking
- Middleware services for collaboration in tactical environments
- Manned/Unmanned Sensor-Decision Teaming efforts
- Increased security, reliability, and availability in ad hoc networks
- Policy based routing with QoS and CoS reliability and availability

Although the primary purpose of this research is to evaluate emerging networking and collaborative technologies, the TSDN campaign provides opportunities to conduct the three distinct types of experimentation: discovery, hypothesis testing, and demonstration. The primary deliverables from TSDN campaign includes: 1) a set of tools and methodologies encapsulated in a well-defined conceptual framework; 2) a set of studies that demonstrate the suitability of emerging sensor and network technologies for operational evaluation; and 3) a repository of networking scenarios, multi-criteria analysis measurements, and models. This effort substantially leverages existing network centric experiment campaign research funded by USSOCOM, OSD and OFT.

NPS's TNT program is in the final process of implementing a Deployable Network Operations Center (DNOC) to support the TSDN collaborative information transfer across various tactical networking topologies. In order to support and bring the DNOC concept to fruition, TSDN architects have invested time and resources to make infrastructure improvements and equipment modifications to a double-wide trailer located at McMillan Airfield, Camp Roberts, CA. Within this DNOC, researchers can study and identify: 1) business processes wherein two or more users collaborate together and agree upon a course of action; 2) the negotiations between the suppliers of information and the consumers of information; 3) the utility of that information in helping tactical users coordinate their efforts; and 4) the roles, functions and tasks that support rich interactions among manned/unmanned sensors and decision makers.

B. OBJECTIVES

Collaborative technology is a critical component of TSDN overall campaign of experimentation strategy. However, it alone cannot address all of the challenges faced by a diverse TSDN team as outlined in Figure 2. It is the goal of this thesis to support TSDN operations with appropriate collaborative technology and not to duplicate or replace functions within its already existing tactical network topology. The DNOC, a Collaborative Technology Infostructure (CTI), integrates collaborative technology that can be implemented to support of TSDN's current and future field experiments.

FY05 TSDN Team

NPS:	- FY 04: 23 Thesis Students, 22 Faculty - FY05: 22 Thesis Students, 31 Faculty (to date) Course Projects: IS, OR, CS
Students	- Joint (SOF, Army, Navy, AF, MC) with OP Experience
CIRPAS	- UAV Field, Flt. Support
IS Dept. (GIGA Lab)	- Networks: Performance, Architecture, Vulnerability Assessment, DoS Collaboration; 3D Terrain, Targeting
OR Dept.	- M&S, MOPs, Human Systems Integration, Insurgency Analysis
CS Dept.	- Networks, Encryption, DoS
DA Dept.	- CONOPS, Mission Analysis
MAE Dept.	- Avionics and Controls, UAVs - AUVs, Undersea Sensor Grids & Coms
ECE Dept.	- Covert Networks, IED Detection and Jamming, Smart Antennas, LPI/LPD
Met Dept.	- Local Meteorology, Radar Threat, EO Performance
Meyer Instit.	- Systems Engineering, MMALV
Instit. for M&S	- Red Team Intent
CDTEMS	- Funding

AF Force Protection Battlelab: Sensor Cluster

ONR/NRL 113: Experiment Support

MIT/ ONR : EWall Collaboration and Data Fusion Testbed

Virginia Tech: Antennas

USSOCOM :
- Funding, UAVs, UGVs,
- Requirements
- Contractor Team Mgmt.

USASOC: SOF Personnel

A.F. Big Safari: Funding

Office of Force Transformation: Funding, Wolf PAC, TACSAT

VC-6: TERN UAV Flight Support

SPAWAR: GIG-EF

NSA NTIO: SIGINT

LLNL:- Cooperative Research
UWB: Coms, Radar, Sensors
IED and Tracking
Radiation Detection
Voice Recognition

AFSOC: UAV Operations

Camp Roberts ANG : Vehicles, Small Arms

NAVSOC: NAVBOARD

DLI: Language, Team Support

Inter-4 :
- Tacticomp, NAVBOARD, UWB

Redline Communications: OFDM/ 802.16

Mesh Dynamics – Multi-Radio Mesh

ITT: Mesh

SAVY: RFID

CenGen: SecNet-11 for MANET

GENEX Technologies: Sensors & UAV Payloads

Fortress Technologies: Encryption

PowerWAN: Power Grid WAN

Rajant: BreadCrumb

Flarion: 802.20/OFDM Mobile Coms

Media Group: NOC Architecture

Evidenced Based Research: C2

MCTSSA: Ruggedizxed PDA, Radio Coms

Figure 2. TSDN Team

This document exists to support TSDN's current vision and strategy. It is not a Standard Operating Procedure (SOP) or a Concept of Operations (CONOPS); instead, it can be considered a transformational roadmap that will provide direction for the introduction of a DNOC into TSDN's campaign of field experiments.

It is the author's hope that the DNOC fits the organization, its needs, and is implemented in a manner most appropriate for the TSDN team. It is important for all of TSDN's stakeholders to understand the overall purpose and design of this Collaborative Technology Infrostructure (CTI). The bullets below presents what the DNOC is, with hopes of setting realistic expectations for the reader of this document.

The DNOC is:

- A baseline collaborative technology infrastructure that supports TSDN's vision and strategy
- An iterative and incremental architecture design that coordinates and aligns the collaborative technology efforts between all of TSDN's functional areas
- A "dynamic" and changing infrastructure that must be reviewed, reassessed and revised every time the organization's objectives and strategies evolve

C. RESEARCH QUESTIONS

The primary research questions are:

How can the TSDN team design, build, and implement a DNOC that will support TSDN's operations and efforts in researching the nature of networked actors and agents and the implications for command and control, tactical military operations, and collaborative decision making. To answer this question, it was necessary that the TSDN team:

- Analyze areas of Information and Communication Technologies (ICT) relevant to the TSDN operations that support research and experimentation through collaboration, peer review, and the ability to replicate findings
- Solicit and consider innovative and disruptive ideas that are currently used by similar mobile and deployable command centers
- Identify and recommend DoD strategic technology initiatives that could guide TSDN's DNOC existing and future physical and functional infrastructure requirements
- Develop and recommend a TSDN DNOC life-cycle support and oversight process

D. SCOPE OF THESIS

This thesis will provide the DNOC's design, build, and the recommend solutions for exploring and improving the technical and baseline operating processes. The thesis will also offer recommendations for life-cycle maintenance and future upgrades.

E. METHODOLOGY

This thesis will employ the following methodology: a comprehensive review of Command Post of the Future (CPOF) and NCO literature; a survey of current and prospective mobile network command center information sources; observations of TNT experiments; and interviews with the TSDN stakeholders in order to determine end-user requirements.

F. ORGANIZATION OF THE THESIS

The DNOC supports collaborative technologies and baseline operating processes so that TSDN stakeholders can unify their efforts in discovery, demonstration, and knowledge sharing. The thesis is organized to support the DNOC's inception in by:

- Providing an introductory overview of the TSDN's operational framework
- Presenting the focus and foundation on which this Collaborative Technology Infostructure (CTI) was built
- Providing a rationale why the infusing of collaborative technology into TSDN can transform the way an organization discovers knowledge and the way organization manages this knowledge
- Translating interdependent decision making into the ultimate goal of organizational learning
- Describing processes that, when implemented, will provide knowledge practitioners with opportunities to integrate emerging and innovative social-technical processes with existing baseline technologies
- Describing the DNOC's role as a decision support system that, through the concept of information visualization, aids the knowledge practitioner in capturing, synthesizing, and managing relevant data produced by experimental outcomes

- Discussing the underlying DNOC infostructure and related business processes that will enable the use of collaborative technology throughout TSDN’s campaign of experimentation

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II. OPERATIONAL FRAMEWORK FOR TSDN ORGANIZATIONAL LEARNING

A. INTERDEPENDENT DECISION MAKING

Interdependent Decision Making is the critical focus of TSDN operations. Every activity that is carried out throughout TSDN research should strive to increase interdependent decisions and build mutual awareness and understanding. The DNOC conceptual design was structured to fit within the TSDN operational framework, as illustrated in Figure 3, in which interdependent decision making is supported by well synchronized communication, negotiation, and coordination processes; and appropriate supporting collaborative technologies.

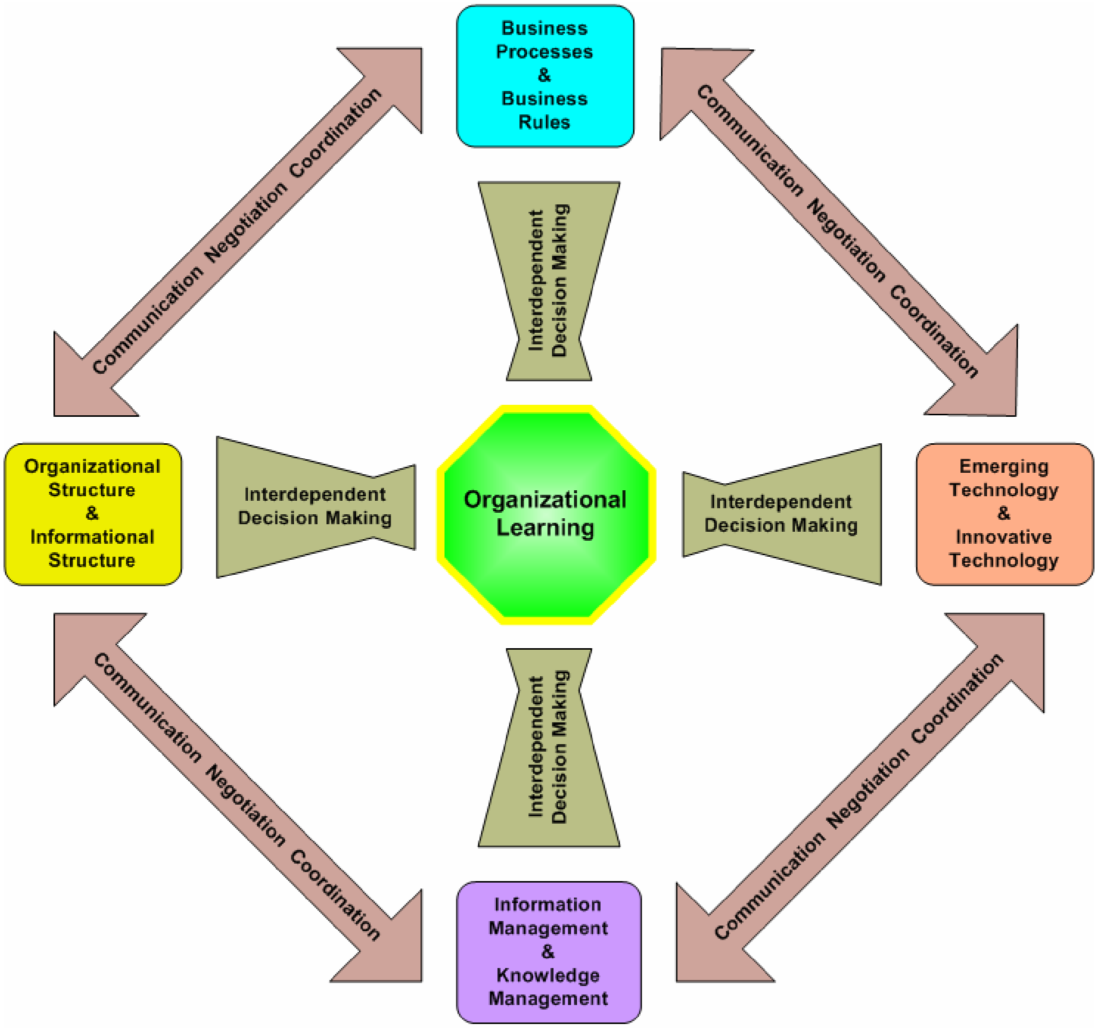

Figure 3. TSDN Operational Framework

The current TSDN operational framework models four mesh-like confluence nodes that leverage value-added information between each node through transactional links. The confluence nodes consist of: organizational & informational structures, business processes & rules, emerging & innovative technologies, and knowledge & information management. As depicted in Figure 3, the confluence nodes are connected by transactional links that represent conduits for communication, negotiation, and coordination processes that enable interoperatability and feedback across the nodes. The transactional links involve mediation, cooperation and agreement on protocols concerning when, where, what, why and how information is collected, fused, analyzed, and disseminated within the organization's infostructure. Coordination and cooperation is usually presented in the military context of unifying physical, social, and cultural efforts during warfare activities and/or operations other than war. However, coordination and cooperation can also take place in the context of cognitive activities such as perception, attention, memory, and decision making. All of these cognitive domain processes can potentially benefit from the synergistic and synchronized actions of more than one individual, just as physical, cultural, and social domain activities do (Gold, p.33, 2005). These synergistic and synchronized cognitive efforts in turn enhance interdependent decision making, and therefore evolve into organizational learning.

The concept of organizational learning is the collective capacity to learn at all levels of the organization rather than a top-down hierarchy of command directives for individuals to act on as orders. Such collective learning requires interdependent decision making and trust among the team members with individual strengths compensating for individual weaknesses (Senge, p. 9, 1992).

The power of organizational learning stems from a vast diversity of team talent and innovation, not from any set principles or heuristics. A learning organization evolves many incremental and iterative although imperfect methods. Eventually, very few interdependent decisions and actions come to depend on single mechanisms. Instead they emerge from conflicts and negotiations that occur as a result of collaborative processes in search for mutual understanding (Minsky, p. 308, 1986). Gestalt psychology identifies this as the group dynamic of a common enterprise where each knowledge practitioner shares insights in a synergistic manner to create something more meaningful than each member could individually (Hayes-Roth & Amor, p. 133, 2003). In the same context, Hutchins quotes Feldman: “Many parts of an organization must coordinate their behavior in such a way that each can cope adequately with the pressures and constraints it has to satisfy” (Hutchins, p. 347, 1996).

The TSDN operational framework is classified as a bottom-up, functional aggregation of components and attributes, structured to provide the supporting elements of interdependent discovery, hypothesis testing, and demonstration—a continuous process of organizational learning. At a high level of abstraction, one can view the operational framework as an integrated network of transactional and transformational mechanisms that influence and shape information. The TSDN operational framework became the DNOC’s baseline conceptual framework. When this baseline is combined with advanced capabilities for intelligent network and sensor management, it will provide end-users with the flexibility to tune the infrastructure and synchronize information transport and processing in support of TSDN operations. In addition, the TSDN operational framework illustrates the importance of proper integration and alignment of key organizational components, including collaborative technology. Each component is dependent on the others, and they must all be well interfaced for the TSDN team to be truly successful in their collaboration efforts.

Each of these components is addressed in the DNOC’s integration into TSDN’s operations, including how the experiments are supported by collaborative technology. The DNOC’s collaboration technologies are designed to be robustly interoperatable, although always in support of interdependent decision making. The DNOC’s conceptual framework is an abstract representation of the guiding principles of the DNOC’s development—all collaborative technology within TSDN, whether organic or inorganic to the DNOC, should exist to enhance and support the TSDN team’s interdependent decision making during a campaign of experiments.

The DNOC can support many of TSDN’s goals by:

- Increasing Interdependent Decision Making
- Providing a venue for developing organizational learning through immersion within a Virtual Learning Environment (VLE)

- Motivating knowledge practitioners in becoming interdependent explorers and discoverers
- Developing facilitators to be integrators of complex, disruptive, and innovative experimentation
- Engaging sponsors to be ardent supporters and drivers of TSDN's efforts

To achieve the above goals, the TSDN team must fundamentally change, or inextricably transform the way that the TSDN team conducts experiments and manages the experiments' outcomes. To help illustrate this organizational transformation, the reader is prompted to refer to Figure 4, the transformational core of TSDN's operational framework, as a guide. There are three stages in this transformation core: Mutual Awareness, Dynamic Reflection, and Organizational Learning.

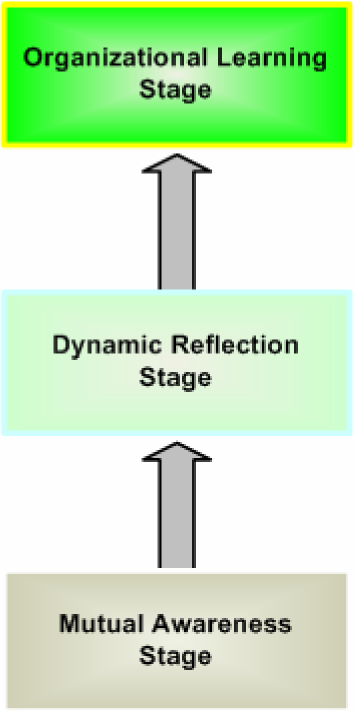

Figure 4. Transformational Core

1. Mutual Awareness Stage

In the Mutual Awareness Stage, the focus is to generate mutual awareness of the need for change itself and that the use of collaborative technology can support increased interdependent decision making. Common activities within this stage include numerous discussions focused on understanding collaborative technology concepts and causal or experimental use of collaborative technology tools. Examples of mutual awareness activities within TSDN include:

- Encouraging the exchange of ideas and thus provide a breeding ground for innovative ideas
- Creating a culture that fosters and incubates social-technical transformation
- Understanding the value-added and the contribution of intellectual assets and increasing their efficiency, effectiveness, and exploitation (KPMG, p. 2, 1999)
- Motivating the exploration and discovery of emerging and disruptive technologies
- Developing an organizational award system to encourage the development of creating, sharing, and reusing knowledge
- Generating value-added organic knowledge and exploiting relevant in-organic knowledge

There are key elements that create a culture that fosters disruptive innovation. These elements include flexibility, adaptability, a willingness to take risks, open communication without regard to hierarchy, a sense of responsibility and accountability that replaces authority, and last but not least, a commitment to success that goes beyond functional roles.

Mutual awareness between knowledge practitioners and collaborative technologies can be achieved in TSDN operations through specialization of a common network vocabulary, SNMP (Simple Network Management Protocol) and MIB (Management Information Base) views for example, by increasing the use of contextual icons and a common use of shared syntax and semantics, which in terms of its structural forms will be most suitable for TSDN problem framework (Druzhinin & Kontorov, p. 176, 1972). Currently, much of TSDN’s organization is in the Mutual Awareness Stage. The TSDN team must facilitate the transition of the organization from this stage through the next stage—Dynamic Reflection Stage.

2. Dynamic Reflection Stage

The Dynamic Reflection Stage serves as a transitional period for knowledge practitioners to develop better understanding of collaborative technology. Dynamic reflection provides increased transaction rates for the practitioner to understand the uses of the collaborative technology by applying it to everyday tasks and processes. In this stage, collaborative technology mimics typical practices by making them easier, faster, or more accurate. Training and everyday emersion typically facilitates the adoption of collaborative technology into field experiments. However, the danger exists that knowledge practitioners often do not move beyond this stage to Organizational Learning. Without moving to Organizational Learning, the TSDN team risks doing the same things it has always done, but at the expense of using more resources. Examples of dynamic reflection activities include:

- Using shared workspaces (middleware, groupware, etc.) as the primary means to collaborate
- Capturing and recording insight and experience and making these cognitive attributes accessible and usable when, where needed, and by those requiring them (KPMG, p.2, 1999)
- Co-iterating and co-evolving organizational relationships that dynamically adapt to context dependent challenges
- Using collaborative workspaces as the primary tools to plan, organize, and execute scenarios
- Conducting TSDN operational planning, tasking, and execution through the use of high quality and highly interactive multi-media hardware and software agents
- Gathering and tracking discipline information in a dynamic data collection repository instead of solely using After Action Reports (AAR), lessons learned documents, and best practices to record historical significant events and experiment outcomes

As a result of mutual adjustment and consistent use of shared collaborative workspaces, the TSDN team will transition through the Dynamic Reflection Stage and into the Organizational Learning Stage.

3. Organizational Learning Stage

Ultimately, the TSDN team must move to the Organizational Learning Stage through the pervasive and integrated use of collaborative technology and the willingness to fundamentally change the way team collaborates. In this stage, users focus on creative and innovative methods to achieve goals and objectives and not solely on the collaborative technology. The end user must master how to understand and integrate the collaborative technology to not only sustain innovation, but to achieve new levels of disruptive innovation (Alberts & Hayes, p. 9, 2003). The focus is no longer on learning technology applications, but on effectively addressing discovery, hypothesis testing and demonstration phases of experimentation. The TSDN team must develop, implement, document and track their failures, successes, and best practices. This information should be shared freely throughout the organization. Some examples of multiplying the effect and potential of the Organizational Learning Stage include:

- Knowledge Practitioners taking ownership for learning and TSDN becoming knowledge practitioner led; fundamentally changing the researcher/student relationship
- Higher rates of interdependent learning that ultimately broadens experience and knowledge base
- Interdependent decision making through team exploration and discovery
- The increase of quality interactions between knowledge practitioners that are connected and engaged in a collaboration environment through the use of a common Knowledge Portal
- Facilitators ubiquitous access to resources which allows them to push and pull information in a rich organizational learning environment

The use of collaborative technology alone will not guarantee successful organizational learning, but rather it will occur through the TSDN organization’s desire and ability to transform their organizational and operational processes. To the extent that the acquisition of a useful adaptation to a changing environment counts as organization learning, collaborative technology can be employed to support such an adaptation (Hutchins, p. 349, 1996).

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III. KEY COMPONENTS OF ORGANIZATIONAL LEARNING

To affect long lasting, positive organizational learning, the TSDN organization must effectively address four key components: Vision & Strategy, Knowledge Practitioners, Business Processes, and Collaborative Technology. To support TSDN membership, knowledge practitioners must align and integrate these components for the greatest opportunity to reach their goals of increased interdependent decision making. During the DNOC's development process, strong consideration was given to each of these components to ensure proper alignment and integration.

A. VISION & STRATEGY

Social, cultural, and business theorists emphasize the need for organizations to share a clear vision and strategy of where they are and where they are going. Efforts to promote this are even more critical when the TSDN team has been recently put together (ad hoc) to operate for a limited time on a specific task. There is a great deal of evidence to indicate that organizations and individuals that mutually share a vision and strategy will trust and work effectively with each other (Whyte, p. 337, 1999).

TSDN excellence is tied inextricably to its intellectual resource capital and vitality. The DNOC CTI must support that vitality by supporting knowledge practitioners, their business processes, and their baseline technologies. Transformation is necessary to ensure that TSDN's experimentation campaign supports the requirements and vision of USSOCOM. USSOCOM's vision and strategy are based on a continuous process of innovation and experimentation of social-technical performance capabilities that provide a useful utility to the end-user—the warfighter. To that end, TSDN's research vision and strategy should champion leadership in the discovery, hypothesis testing, and demonstration of emerging and disruptive technologies. This vision and strategy must be focused and well articulated to align all activities throughout the TSDN organization and provide the impetus to transform. Vision and strategy are clearly the drivers of the other three components and are the conceptual foundation of the DNOC.

B. KNOWLEDGE PRACTITIONERS

Enabling organizational learning takes more than processes, technology, and information—it takes the result of people working together as a synergistic and highly synchronized team. Future innovative and disruptive technology research drives knowledge practitioners towards an unprecedented level of interdependency. TSDN's practitioners should be empowered with knowledge, experience, skills, and tools so that they will be more effective and productive to support increased interdependent decision making. As TSDN research enters a future of complex experimentation, it is imperative that the TSDN team creates an environment that meets the ever-changing and diverse needs of its stakeholders. However, appropriate and adequate levels of time, resources, and training must be allocated to facilitate the massive cultural change TSDN team members will experience as they infuse collaborative technology throughout their organization. The functions, roles, and tasks of knowledge practitioners, facilitators, and administrators change, as each stakeholder group co-evolves and takes responsibility for transforming and adapting to new and ever-changing collaborative environments.

The most important way to address the people component is through effective Tactics, Techniques and Procedures (TT&P). For example, through effective and efficient use of TT&P, TSDN stakeholders will have greater understanding of the tools available to them to transform the organization; and administrative functions can be streamlined, making it easier for the organization to accomplish its goals during experimentation. Greater knowledge, mutual awareness, and the supporting capabilities of collaborative technology will empower stakeholders to create innovative positive change within the TSDN research environment.

C. BUSINESS PROCESSES

The business process component is critical in improving the overall efficiency and productivity of TSDN operations. New streamlined business processes will foster interdependent decision making. Business processes can be considered the "mortar" that holds the other three components together. A business process is created to effectively and efficiently perform a function, role, or task. Without clear business processes in place, valuable time and resources are squandered at the expense of organizational learning. It is important to understand that business processes must be iterative and incremental, making it imperative that the organization's purpose is to increase its ability to adapt to changing environments and conditions. While the primary focus for the DNOC is to support mutual awareness and interdependent decision making, it is clear that baseline and flexible business processes within this infostructure, would allow the TSDN team to quickly adapt and respond to the multitude of changes that are inherent in a complex and dynamic experimentation campaign. Ultimately these business processes should supplant, foster, and incubate disruptive innovation (Alberts & Hayes, p.52, 2005). Consideration of streamline and efficient business processes must drive technology selection, implementation, and integration.

D. COLLABORATIVE TECHNOLOGY

Collaborative technology should not drive knowledge practitioners and business processes; rather it should support interdependent decision making and organizational learning. Collaborative technology should facilitate the interdependent information collection, analysis and decision making processes throughout TSDN's campaign of experimentation. TSDN facilitators should provide knowledge practitioners with a suite of collaborative technology tools necessary to infuse technology into the everyday learning processes of the organization. These tools and their implementation must be aligned with TSDN's overall campaign of experimentation vision and strategy.

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IV. ORGANIZATIONAL LEARNING: DNOC’S DESIGN FOCUS

Collaborative technology alone should not be the only design focus for the DNOC; another important design feature is to ensure that the infostructure serves as a collaboration support tool for increasing organizational learning. It is imperative that the TSDN infostructure provide more knowledge practitioners, more access, more often, to a wealth of value-information that can stimulate collaboration. Organizational learning during TSDN activities, if properly encouraged and embraced, allows the organization to reap the benefits of synergy from the knowledge held by a diverse group of individuals (Jackson, p. 74, 2003).

As a research treatise, TSDN’s organizational learning is the highest priority and the key to fulfilling the mission of providing high fidelity experimentation. To this end, one of the primary functions of the TSDN facilitators is to provide the resources, environment, and direction that knowledge practitioners need to achieve results. Any plan for improvement cannot succeed without placing organizational learning at its forefront. There are many ways that organizational learning is affected. However, since the focus of the DNOC is to infuse collaborative technology within the TSDN campaign of experimentation, there are system design characteristics in which enhances collaborative technology’s utility in critically supporting increased organizational learning.

A. MUTUAL UNDERSTANDING

Any design plan to increase interdependent decision making should be built upon a foundation of mutual understanding. Mutual understanding emphasizes that TSDN’s members do not gain solely from being presented information; however, they benefit from having the impetus, through self-actualization, to independently seek to discover and gain knowledge.

Keeping mutual understanding at the forefront of DNOC’s development ensures that the activities in the iterative and incremental design phases support increased interdependent decision making. A successful ad hoc experimentation team requires team members with appropriate skills and behaviors, facilitators who know how to quickly assemble an effective team and manage the evolving dynamics in the group, and an organizational culture that provides the right context for the team to succeed. Lacking any one of these factors, an ad hoc experimentation team can easily flounder.

Collaborative knowledge sharing enables the role of the knowledge practitioner in their ability to dramatically improve the fusion of information. Knowledge practitioners must be responsible for their learning experiences and develop skills to become information literate. A quality interactive focus that supports collaborative exploration and discovery will empower knowledge practitioners to achieve and thrive in information-rich environments.

A majority of knowledge practitioners, from early on in their training, education, and careers are exposed to information and communication technologies. Video conferencing, e-mail, chat, cell phones, and a myriad of technology enhancements have changed the way most people collaborate. In order for TSDN experiments to be successful, knowledge practitioners must innovatively explore and discover how collaborative technology can adapt to and work for them, rather than they, the knowledge practitioner adapting to the collaborative technology.

B. LEVERAGING INTERFACES & PROTOCOLS

In order to design a DNOC that was flexible, adaptable, and responsive to user needs, the TSDN team applied systems engineering principles and an "open-system architecture" approach to the concept, design, and build construct as illustrated in Figure 5. The open-system architecture approach is a design methodology where the functions and functional interfaces are well defined (Blanchard & Fabrycky, p. 64, 1998). Implementation of this design methodology requires adherence to a systems engineering process that addresses affordability and performance goals at the architectural level. An open-system architecture approach is characterized by the following:

> 1) Use of standards which are developed/adopted by industrially recognized standards bodies; and 2) Definition of all aspects of system interfaces to facilitate new or additional systems capabilities for wide range of applications; and 3) Explicit provision for expansion or upgrading through the incorporation of additional or higher performance elements with minimal impact to the system - IEEE POSIX 1003.0/D15

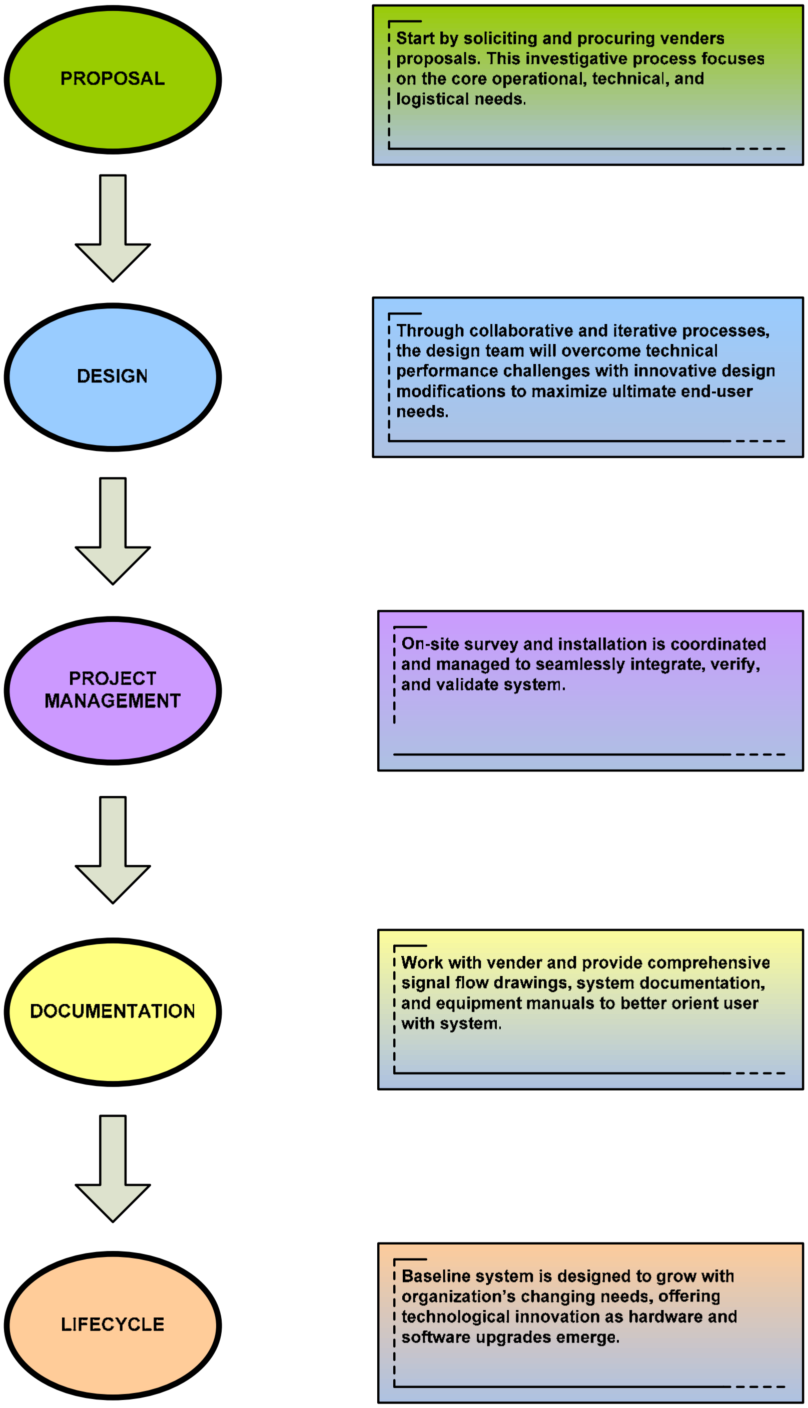

Figure 5. DNOC Design, Development, & Implementation Process

C. CURRENT & PROSPECTIVE DESIGN CONSIDERATIONS

After surveying various command centers, it was quickly assessed that advance technology NOCs require an extensive array of power, network, and AV (Audio/Video) cables in order to achieve successful integration of a multimedia and collaborative workstation environment. The need for a deployable system requires the necessary components to quickly establish a system within the confines of a double-wide trailer. The hardware that could achieve this included a framework to support large plasma screen displays, a multimedia projector, as well as cable management of the myriad power, data, phone, and AV cabling. The system must have embedded network switches to optimize cable management. This scaleable DNOC system should provide modular components to support tactical communications, computer data systems, and multimedia video display systems. This incremental project effort consisted of soliciting, procuring, and managing vendors during the design and development phases of integrating computer equipment, command center furniture, AV display systems, and deployable transit cases with associated accessories. The majority of components that were integrated were commercial-off-the-shelf (COTS) items that require little or no modification. The vendors would be expected to provide on-site technical and logistics support. In order to support mobility requirements, the system must be able to be deployed in protective transit cases and must be transported by civilian or commercial vehicles.

1. Design Considerations

Five design considerations were applied during the DNOC development process:

1) Operation and impact of current TNT NOCs during field experiments
2) Anticipated operation and impact of DNOC during field experiments
3) Availability of resources to meet budget and schedule constraints
4) Life Cycle Maintenance required to support and upgrade DNOC
5) Training and learning required to ensure proper use of the DNOC

2. Information Visualization

In previous field experiments, the information was displayed using computer projectors and pull-down screens. The DNOC design team sought to improve the information display quantity and quality by incorporating five 50” plasma screens. Plasma screens are easier to set-up (no concern for focal length and weight), provide a sharper image and experience minimal washout due to ambient lighting. Additionally, the dimensions of the DNOC were such that the maximum distance any participant would be from a display was no more than a few feet, allowing sufficient field of view (170°) and resolution for all but the smallest text sizes. The DNOC team contracted the technical services of Media Systems Group, an AV integration firm, to install the plasma and projector display equipment. The DNOC displays allowed operators to see more details with better clarity, facilitating rapid assimilation of visual information. The plasma displays can accept numerous input modes (RGB, DVI, etc.) and can be optionally configured, through the use of a matrix switcher, to display these feeds in a multi-screen matrix format. This increased functionality improves the users' ability to manage data sets, video, and audio streams from multiple sources.

Components obtained were integrated with current TSDN equipment to provide maximum scalability to support configurations required for future employment and upgrades. All contractors and vendors were leveraged to provide installation, on-site technical and life-cycle support; minimizing a large logistical footprint. While no requirement for ruggedized (MilSpec) equipment or transit cases was articulated, components were purchased that allowed for not only portability but durability as well.

3. Server-Centric

The DNOC uses portable, mil-spec transit cases, with integrated 19 inch racks, to mount and operate a variety of computer and networking equipment. Common to each case is an Uninterruptible Power Supply (UPS), 1U monitor/mouse/keyboard KVM and router with integrated 16-port switch module. Each case has sufficient space for additional equipment such as servers to support a variety of applications and services. This modularity allows users to rapidly reconfigure a case to support unique experimentation requirements. Future upgrades to these cases should include a server to support print, network management and collaborative services. This will reduce the ancillary and often redundant burden associated with standalone hardware. Figure 6 illustrates the top level architecture of the DNOC.

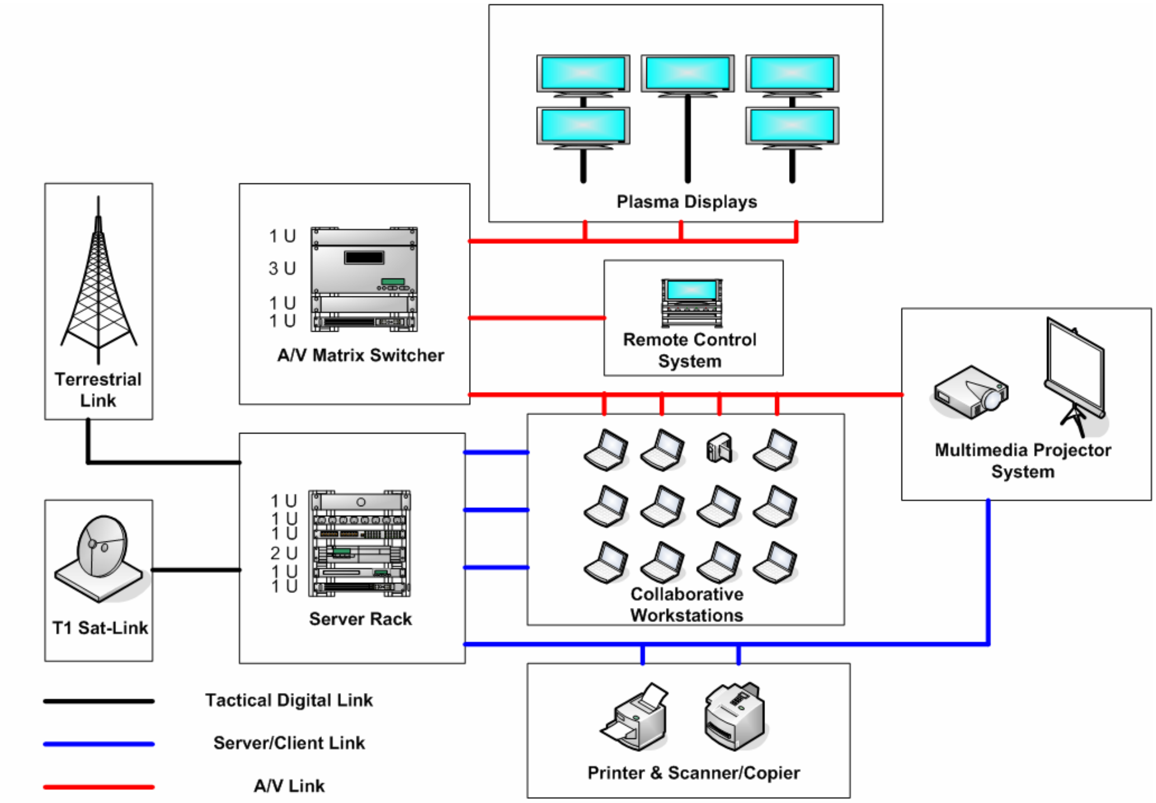

Figure 6. DNOC Top Level Architecture

4. DNOC Mesh: Network of Cooperative DNOCs

The DNOC's design framework is a flexible and modular design that can expand and accommodate a wide variety of communication protocols and formats. The DNOC design attempts to simplify the automation and integration of audio-video, network and communication technologies through intuitive user interfaces. As illustrated in Figure 7, the DNOC serves as a deployable facility that can mesh with other fixed and mobile NOCs, manned/unmanned vehicle sensors, and decision makers. Examples include the NPS Global Information Grid Applications Lab (GIGA Lab) fixed NOC, a future sea-based NOC aboard the commercial diving vessel Cypress Sea, a ground-based mobile Light Reconnaissance Vehicle (LRV), and man-packable NOCs.

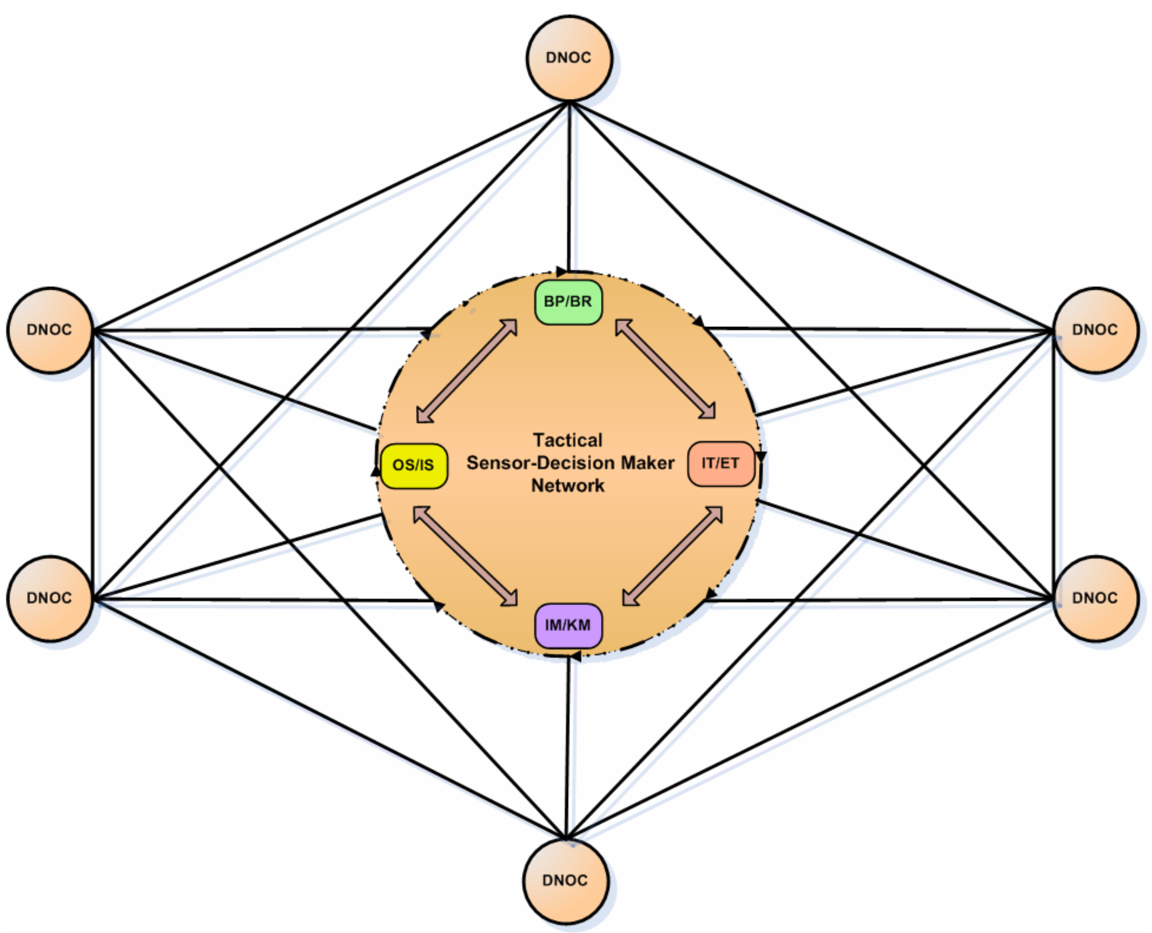

Figure 7. DNOC Mesh

TSDN's mesh network of Deployable NOCs will encourage research in a variety of disciplines. With diverse ad hoc technologies emerging, the TSDN team seeks to aggregate and exploit key elements of these technologies, as well as study the qualities of the communication and collaboration protocols. It is analogous to the concept of studying human behaviors that emerge during communication, negotiation, and coordination processes. TSDN experimentation continues beyond the discovery and hypothesis testing phases of experimentation and facilitates the demonstration of refined operational concepts.

Future researchers and students can use the DNOCs to study new protocols and processes in an effort to exploit emerging information and communication technologies. These infrastructures offer a research platform to study both local area and long-haul wireless capabilities with open-system architectures and standards. Additionally, these future DNOCs will support a repository of wireless networking scenarios, performance capability packages, network and sensor modeling. Although there will be considerable opportunities to study the behavior of wireless mesh networks, there also now exists a testbed to research social-technical teaming efforts involved in tactical sensor-decision maker networking.

Ultimately the DNOCs should provide a unique plug-and-play environment for TSDN experiments involving ad hoc networking. It has the capability to facilitate exploration and discovery of different network-centric technologies and protocols. It is the author's hope that the DNOC's Audio Visual Multimedia (AVMM) system will be easy to deploy, manage and operate; all of which translates into increased collaboration and productivity, greater flexibility, faster decisions, lower costs and improved interoperatability.

V. HIGH FIDELITY EXPERIMENTATION ENVIRONMENT

In the spirit of David Alberts' and Richard Hayes' proposition facilitating pathways to innovation and transformation, a high fidelity experimentation environment will have essential collaborative elements properly aligned and integrated to support disruptive innovation (Alberts & Hayes, p. 83-90, 2005). In many ways, this high fidelity experimentation environment is what one might envision when asked: What will robust net-centric operational experimentation look like in the future?

A. RICH COLLABORATION ENVIRONMENT

A rich collaboration environment must be designed to take advantage of the opportunities that collaborative technology brings for improved collaboration whether co-located in or virtually linked to the DNOC. Knowledge practitioners will need to access knowledge resources and information from reputable sources. The DNOC, as a CTI, enables them to expand their information reach, richness, agility, and mutual assurance (Hayes-Roth, Comments on NCOW RM 1.01, 2004). A rich collaboration environment should address the following key elements of collaboration:

1. Virtual Learning Environment

Knowledge practitioners must have access to high quality content within the proper context. Collaborative and Web technologies have the capability to provide practitioners with a variety of Virtual Learning Environments (VLEs) and functionality, with more options for obtaining relevant information and knowledge. If collaborators are to take responsibility for their collective learning, then they must be provided more choices and options to what is available within their research interest; a VLE, where knowledge practitioners have ready access to the information and tools necessary to interdependently do their research efficiently and effectively.

2. Highly Skilled Facilitators

Facilitators are the heart of any research organization and understand a research problem as an opportunity to learn and a chance to improve the organization. Because facilitators seek to leap outside the conventional to find the innovative, they align the organization's vision and strategy so that organizational activities can adapt to new learning discoveries and improve the experimentation process (Conger, pp. 6-7, 2004).

They must be equipped with the tools and understanding necessary for organizational learning success. Facilitators need intuitive tools to access and disseminate information that will impact the knowledge practitioner’s success. Effective organizational learning, involving collaboration among all stakeholders, drives an iterative and incremental process of discovery, hypothesis testing, demonstration, and acceptance. Successful experimentation with emerging and disruptive technologies depends on the ability of the facilitators to focus on technologies that can be matched to compelling end-user needs. Managing this complex collaborative interaction requires facilitators who understand and respect values, working styles, cultural biases of different groups (military and academia), and who can also effectively initiate and sustain communication among the stakeholders across all organizational and institutional boundaries (National Research Council, p. 2, 2004).

3. Database Repository

Information will be logically organized and categorized based on the knowledge practitioner’s needs and habits. Information can be captured in a centralized database repository for search and archive. A historical analysis of past experimental data and time-stamped screen shots are important sources of insight into value-added discovery and hypothesis testing. A multitude of data is available from each experiment that can provide insights into the relationship between the degree of situational awareness and the quality of information (Walter, et al., 2003, p.xxvi).

4. Knowledge Portal

A knowledge portal has the potential to become a one stop shop for TSDN asynchronous collaboration—a portal that provides knowledge capture and transfer of expertise and experience between knowledge practitioners. This knowledge portal can serve as an integration mechanism that aggregates applications, content, and data. Knowledge practitioners should be able to design and tailor this knowledge portal to access rich and relevant information. This portal should provide access to specific, individualized content on the user’s tailored homepage through both system personalization and user customization. For example, knowledge practitioners can manage their community of interest, team, and group pages they desire to access directly from this homepage. Familiarizing oneself with postings, navigating through pages, and managing content within context can improve situational awareness; thereby situational understanding can likewise be reinforced.

5. Common Relevant Operational Wall of Networking

The CROWN provides a virtual view and access to dynamically accurate, fused and relevant situational information. This situational information can be tailored to any level to meet requirements of the knowledge practitioners. This CROWN fuses both situational awareness and situational understanding horizontally and vertically. The Crown enables the knowledge practitioner to place information into a number of different displays. In this way, the information becomes modular in that it can be moved and viewed in a number of ways, depending on the display selected.

6. Knowledge Portfolios

Knowledge portfolios help knowledge practitioners display their past and current research efforts. Knowledge portfolios provide the ability to communicate knowledge practitioner’s best practices easily and efficiently. Accessed through the knowledge portal, practitioners can capture and build upon their best practices throughout their work efforts.

B. UBIQUITIOUS KNOWLEDGE SHARING

Knowledge sharing has no temporal or physical constraints. Knowledge sharing can occur anytime. TSDN administrators can provide knowledge opportunities 24/7. Assuring that all knowledge practitioners have equitable access to knowledge is critical to the success of TSDN goals and objectives today and in the future.

An example of an enabler of ubiquitous knowledge sharing is the knowledge portal mentioned earlier. A knowledge portal would aggregate and illuminate knowledge sources for NPS students, instructional content for facilitators, and administrative tools for field experiment coordinators. It would offer all TSDN constituents a way to support organizational learning. Knowledge practitioners will have unprecedented ownership of their learning and the ability to further their learning anytime from anywhere.

Facilitators should encourage knowledge practitioners to access the knowledge portal anytime, and tap into the best practices of researchers anywhere. Researchers and students will be better able to support interdependent innovation and discovery by more effectively using information resources gathered prior, during, and after TSDN experiments and leveraging this information in exchange for knowledge.

1. Knowledge Sharing

There should be an easy-to-follow knowledge sharing process supported by a collaborative technology environment for knowledge exchange, retrieval, and collaboration; and the relevant tools for communication, negotiation, and coordination (MerDermott, p. 47, 2001). To this end the DNOC is wired with high-speed access to the TSDN intranet and the world-wide internet. When the TSDN team completely enters into interdependent exploration and discovery, a rich collaboration environment and ubiquitous knowledge sharing will be seamlessly integrated. TSDN experiments will have self-directed knowledge practitioners capable of employing all tools available to them to seek out knowledge and support dynamic team focus. The knowledge practitioners will work in team-based situations, and support each other to achieve individual and organizational learning goals. They will be enabled and thus responsible for designing their own work, to experiment with ideas without fear of failure, and to care enough to selflessly undertake these functions, roles, and tasks. The facilitator’s function and role should be that of a coach, trainer, coordinator, and collaborator. They will facilitate a knowledge practitioners desire to obtain and share knowledge by aligning their goals with the organization’s goals. They will also work with other facilitators to disseminate the best practices generated from alike communities of interest and to integrate core competencies in all research areas. All TSDN stakeholders will have ubiquitous access to TSDN resources and information that supports both a rich collaboration environment and ubiquitous knowledge sharing.

2. Knowledge Management

The fundamental baseline component of the DNOC infostructure is a focus on the processes of ubiquitous knowledge sharing and organizational learning. Everyday, facilitators will use various methods, tools, and techniques to engage knowledge practitioners, looking for the spark that occurs when the practitioner becomes engaged and embraces the knowledge sharing process. Historically, facilitators have used traditional methods, tools, and techniques – many of which did not rely on the use of collaborative technology. It is the author’s belief that collaborative technologies, only after gaining the confidence and trust by the end-user, can transform current TSDN's practices and provide unique and compelling reasons for knowledge practitioners to be engaged.

To fully support TSDN team efforts to transform their process of exploration and discovery into ubiquitous knowledge sharing, TSDN facilitators must focus on activities required within each of the key organizational elements: vision & strategy, knowledge practitioners, business processes, and collaborative technology. The overall strategy for transforming the business process of ubiquitous knowledge sharing is to build TSDN's infostructure capacity to leverage information through comprehensive knowledge management development. Additionally, facilitators should be provided the tools and resources necessary to infuse collaborative technology into TSDN operational planning, tasking, and execution. TSDN knowledge practitioners will begin their own personal transformation of ubiquitous knowledge sharing as they apply new collaborative technologies to their every day interactions and negotiations.

By appropriately applying collaborative technology, the TSDN team will have the ability to promote ubiquitous knowledge sharing in a way that facilitates organizational learning. In addition, TSDN team will provide new ways for knowledge practitioners to gain access to information and knowledge opportunities.

Throughout DNOC's development process, the TSDN design team will embark upon a journey to develop adaptive, flexible, and responsive technological solutions. It was TSDN's organization teaming effort and commitment to use collaborative technology to transform its organization learning processes, to identify what works, and to integrate collaborative technology into everyday practices throughout the organization. To do so, it was necessary to identify those collaborative practices that work best for the TSDN research environment and the diverse range of knowledge practitioners.

3. Business Process of Collaboration

Another component of the DNOC infostructure is the Business Process of Collaboration in which the focus is on improving the business process and business rule transactions. The "business transactions" of TSDN operations should be managed through an integrated system with efficient and automated processes, while effectively minimizing cost and resources. Similar to private sector business, TSDN operations creates numerous business transactions that must be captured and processed, such as soliciting the services of a contractor or vendor for providing field equipment and experimentation support.

Collaborative technologies and groupware are the primary tools to track, process, capture and report experiment goals, objectives and results. Principal investigators rely on this groupware to make sound decisions in the best interest of the TSDN program. TSDN's information needs will progressively change and therefore its ICT systems must also progressively change. ICT systems has different roles to play as collaborative technologies are established to evolve TSDN business processes—it moves from being the underlying infrastructure to the linking mechanism, to the support infostructure (Pan & Leidner, pp. 71-88, 2003).

4. DNOC Transformation

A final component of the DNOC is the Collaborative Technology Infostructure. While collaborative technology does not directly transform TSDN operations, it must be in place to allow for the transformation of facilitation and ubiquitous knowledge sharing practices.

The integration of TSDN efforts related to vision & strategy, knowledge practitioners, business processes, and collaborative technology are critical to the TSDN's program success. In the CTI component, TSDN strategy is to put in place a DNOC that fully supports TSDN's current and future needs in both the process for knowledge sharing and collaboration. Through targeted professional development and well-executed Concept of Baseline Operating Processes (C-BOP), the TSDN team will develop a strong understanding of the importance of the DNOC and the accomplishment of short and long term objectives. It must be understood that there are no "short-cuts" or "easy answers" to building a DNOC to support the large scale and scope of TSDN's campaign of experiments. An established set of realistic expectations from TSDN stakeholders will greatly facilitate implementation of efficient and effective activities within the DNOC. As the TSDN team enhances and improves the DNOC, it must also implement best practices observed from past experiments to improve, maintain, monitor, and manage future field experiments conducted from, in and around it. It is the author's ultimate desire that the

CTI component of the DNOC becomes a seamlessly transparent decision support system for knowledge practitioners conducting TSDN operations.

C. INTERFACE MANAGEMENT

1. Interfaces

The DNOC incorporates network hardware and software that supports wireless protocols of voice (Voice over Internet Protocol), data, and video signals from other experimentation sites, fusion centers, and GIG-BE research platforms. Although the DNOC is capable of upgrading to support video teleconferencing, the current configuration of this equipment supports 802.11x, 802.16x, and 802.20x wireless protocols. Additionally, configuration changes and additional hardware components will be necessary to enable hybrid wireless-mesh networking. Hybrid wireless-mesh networking is a concept of using different wireless networking topologies and hybrid communication infrastructures that support robust voice, data and video in addition to the composite aggregation of performance, fault, and configuration topology management.

Interdependent exploration and discovery will be aided by the ubiquitous sharing of knowledge to key users. Operational efficiency will also be achieved by providing accurate and relevant information to key operators. The TSDN team is currently implementing a knowledge portal and CROWN to aid knowledge practitioners in their interdependent decision making during TSDN operations. However, the knowledge portal and the CROWN does not provide the application of task functionality of the information communication system, but rather aggregates the information and makes it conveniently accessible to the DNOC knowledge practitioner when requested.

It is the intent of the author that the DNOC is transformed into a completely integrated Collaborative Information Environment (CIE) that has the capability of supporting and leveraging GIG voice, data, and video protocols throughout TSDN’s campaign of experimentation life-cycle. The DNOC team’s design perspective was to build an open-system architecture that could meet the constantly increasing needs of the researchers, students, vendors, sponsors, TSDN administrators, and other stakeholders. The applied network baseline operating processes incrementally define and reflect the currently recognized CTI while still providing a path for migrating to emerging and innovative technologies in the future.

2. Future Upgrades

In addition to the network infrastructure, the DNOC’s next development phase will incorporate information management and application support (hardware and software) that will be updated to provide for common pools of storage, centralized backup and recovery, and centralized security for all TSDN applications. This phase will include server-centric equipment at the DNOC site to support site-specific applications. Also the TSDN team will attempt to leverage centralized storage for all sites to simplify management and control of data and facilitate the backup and recovery process.

3. Small Logistical Footprint

The TSDN program will continue to evaluate opportunities to leverage outside expertise from such vendors like Media Systems Group and Wright Line, to provide the highest quality technical innovative solutions and support while maintaining an efficient overall cost structure. In some cases, the cost of outsourcing some key AVMM management functions can more than outweigh the burden of increased personnel training and retention costs for the highly technical skill sets required to support the latest technologies. Regardless of outsourcing opportunities, TSDN stakeholders must retain the responsibility to solicit, procure, and manage outsourcing vendors and contractors when making critical AVMM purchase decisions while minimizing its logistical footprint.

VI. DNOC—NETWORK OPERATION DECISION SUPPORT SYSTEM

A. OPERATIONAL REQUIREMENTS

> …it is also a function of networking—of combining individual perspectives and understandings into a common knowledge. So when we shift from being platform-centric to network-centric, we shift from focusing on "things" to focusing on behavior or action. That is where we find the power. Vice Adm. Arthur K. Cebrowski (USN-Ret.)

In tactical operations, the human-in-the-loop risks becoming the weakest link in the decision-making process unless innovative steps are taken to develop Information and Communication Technologies (ICT) necessary to process and present the information in a manner that the knowledge practitioner can rapidly assimilate. Otherwise, information overload, instead of reducing the fog of uncertainty and eliminating friction, could actually increase both their dynamics and complexity. Uncertainty and friction produces an imbalance in the information-decision flow resulting in decision paralysis. Victory does not always go to the tactician who has the best observation and orientation. It goes to the one that can best process information into knowledge, knowledge into understanding, and understanding into decisive action.

ICT, such as collaborative technologies, wireless hybrid mesh networks, remote unmanned weapon sensors, and in particular, a DNOC acting as a Decision Support System (DSS), enable the execution of Information Operations (IO) in which useful information is made available to the tactical decision maker while denying this same information to the adversary. DSSs "are tools designed and developed to aid decision makers cognitive processes" (Vinze & Sen, p. 391, 1991). If we are truly working toward network-centric goals vice platform-centric, then it is necessary to build a DNOC to support the expeditionary warfighter. No longer should we build systems that the warfighter must adapt to, but build systems to align and integrate to the tactical warfighter's physical and mental needs.

B. MOTIVATION

The importance of ICT in modern warfare systems, especially at the tactical level, is constantly growing. Since the beginning of the 1980's, Artificial Intelligence (AI) has become a significant part of this trend because of its potential applications in military decision making. Currently there is a focus on the decision making process involved with Information Operations/Information Warfare (IO/IW), namely the automation of the decision making through the use of AI embedded into DSS or decision aids; more specifically, an expert system (ES) technology that extensively uses embedded AI capabilities in computer processing, pattern recognition, and anomaly detection. In this era of the ICT explosion, problems in providing the warfighter with too much information have become discerning. Additional problems arise when the military services rapidly adopt NCO concepts without proper attention focused on the long term net effects (outcomes). NCO strategies are the primary catalyst that fuels the research, development, and acquisition of new ICT for support of military transformation—a process that supports the invasion of AI technology into the realm of decision making and information transactions. It becomes clear throughout this discussion that the DNOC can render cognitive assistance to the warfighter in this area. However, the problem of automating cognitive processes in parallel with the development of human-system decision making exposed to battlespace environments has become more complex and dynamic, drawing nearer to the edge of uncertainty.

The complexity of introducing AI in the cognitive processing of a DSS involves a variety of sciences: philosophy, psychology, computer science, linguistics, pattern recognition, anthropology, etc. This complexity can be simplified through efforts that address both the system engineering of quality ICT systems and thorough iterative and co-evolutionary collaboration with the end-user. Improper user-defined requirements result with the warfighter not using the full capabilities of a DNOC; and instead of helping themselves, will only burden themselves with new concerns and worries and will eventually discard using the digital decision aid altogether.

C. COGINITIVE PROCESSING

The search for the best methods of integrating software agents with human-like decision transaction and negotiation capabilities are being conducted steadfastly and vigorously throughout the world. However, the AI research work conducted by the U.S. Department of Defense (DoD) (military, social, technological, psychological, etc.) is not extensively focused at the expeditionary level associated with sensor/effector teaming efforts. AI technology is often only accessible at the strategic and operational level. It is only now slowly making its approach to the tactical level. The question of necessity is heavily discussed among military and civilian research groups who are actively involved with operational research and analysis of Modeling and Simulation (M&S) of military Command and Control (C^2) and IO systems. ICT must not become an end unto itself; otherwise, the warfighter risks developing a mindset that these tools are used as a crutch by cautious information warriors who are paralyzed by analysis and who have unimaginative solutions to situations already overtaken by events (McCann & Pigeau, p. 120, 2000). Meanwhile there is an ever-increasing need to understand the essence of these problems and consequently, to some extent, the essence of human thought, with sufficient clarity, completeness and specificity: the warfighter at all levels including tactical requires a thorough understanding of the methods, scientific tools and techniques involved with decision making.

To extrapolate or forecast events has profound effects in IO. Without foresight it is difficult to make a correct decision. An indisputable rigorous conclusion is often made on the basis of statistical science and situation analysis. It is a willful act performed by the warfighter with consideration of his or her beliefs, values, education, experience and intuition. A relationship between intellectual and behavioral aspects of obtaining situational awareness (SA) can be found by means of a decision loop (Lawson-Moose Cycle, Figure 8). This decision loop models the basic core cognitive levels that the warfighter transitions through when making a decision to execute action.

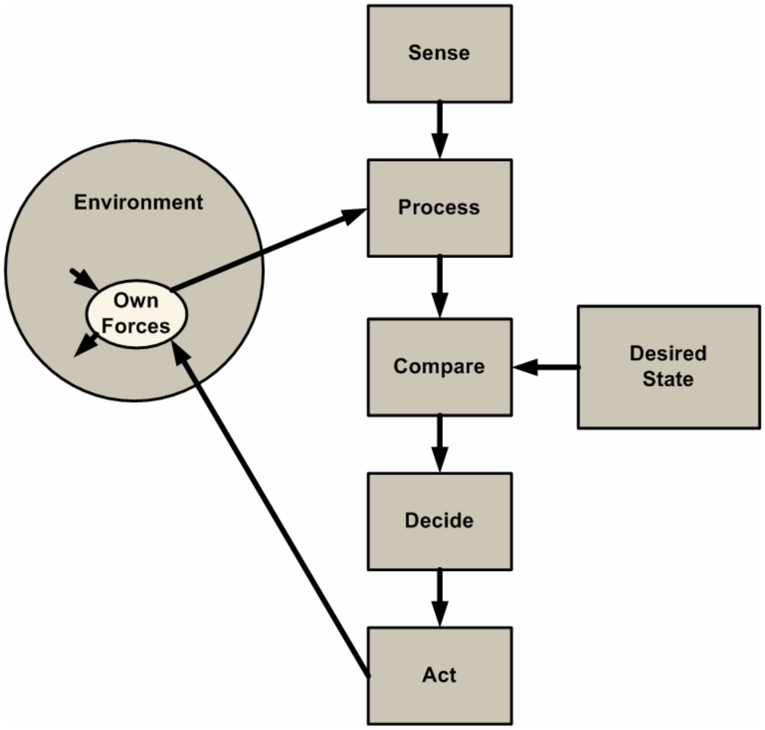

Figure 8. Lawson-Moose Cycle. (From: Lawson)

To support the warfighter's cognitive processes, one must take into consideration the total diversity and complexity of asymmetric warfare. The information warrior deals with many indices, factors, details, often obscure and insignificant at first glance to outside observer. In the warfighters' evaluation of a situation they establish relations between facts, use of heuristics and rules which govern these relations, and on the basis of these patterns, reveal the thinking of the adversary. Limited or insufficient consideration of the facts in their entirety and their interrelationships holds great danger during urban conflict.

However, it is not a simple thing for the warfighter to analyze an abundant amount of facts. In an environment of exponential growth in information available to humans, capabilities to improve and enhance the ways humans deal with information are required. The first step in solving how the warfighter can assimilate information efficiently is to gain a better understanding of how humans work with various forms of data. This requires a significant improvement in the understanding of the immensely complex human mind. The capability to understand how the human mind works in different situations will help improve human mental performance. A required capability for improvement is enhancement of memory since it has been shown that excellent memory helps to develop proficiency in situational awareness. As a result, expedient mental processing functions performed by warfighters and their supporting knowledge practitioners required during course of action planning will vastly increase. To keep up with the fast pace of ICT by simply expanding the military's already limited resources is fundamentally impossible. This would require an inordinate increase in forces and intellectual capital and would not fit into the current transformation concept of a smaller, faster, and more lethal force.

The only solution to this "glare of war" (described by Dr. Howard S. Marsh of the Office of Naval Research as information overload) lies in the extensive application of AI, primarily software agents. ICT already enables warfighters to securely and reliably transmit, receive, verify, and display a massive amount of information within a sufficiently short processing time. In addition, complex logic processing of information can be conducted through data mining and data fusion which are technologies compatible with evolutionary algorithms that compare, analyze, and synthesize meaningful data. All this makes it possible to liberate military forces from data processing, and in turn, force multiplies the intellectual potential (knowledge resource) of the warfighter. Knowledge is perceived as the key to "information superiority" and speed is perceived as the key to exploiting that knowledge (Adams, p.58, 2001). Another aspect is that software agents do not simply help the warfighter fuse information into knowledge, but also stimulates the development of the collective military resource of "understanding", in which the largest group of knowledge practitioners, including those separated by great distances, can participate. The critical application of software agent technology is to support the warfighter's cognitive processing in achieving understanding. There are points in the decision making process where human understanding is inadequate because of limitations and/or variability or tendencies to make errors. Software agents would provide support at these points (Modrick, p.462, 1979).

D. IMPROVED QUALITY OF INTERACTIONS

The DNOC is mere component of collaborative technologies that can improve the quality of interactions between tactical warfighters. The Graphical User Interfaces (GUIs) in the DNOC should help to accelerate or slow down the pace of displayed information, depending on the end-user’s input and behavior patterns (Andriole, p.315, 1986). As always in the development of new forms of collaborative technology, we are faced with complex problems of the character and volume of knowledge that the warfighter must possess. Given the enormous variety of collaborative technologies, of course, neither the warfighters nor their resource support are capable of complete mastery of the knowledge and skills needed for all forms of ICTs present in the DNOC.

There is no need for this mastery in the presence of intelligent software agents. All data transactions can be requested in any degree of detail, and can be obtained in the form most suitable for visualization and rapid assimilation to aid in formulating, calculating, and articulating decisions.

In any high stress, high information rate environment, human decision makers can be overloaded and can become unable to assimilate and use all the data available. The future challenge for warfighters is not whether they are going to get the information or not, but how are they going to sort out the appropriate information from the overabundance of incoming data. This is true particularly in sensor data analysis and in information management where data must be evaluated and used effectively in managing sensors/effectors and making tactical decisions under strict time constraints. Intelligent software agents offer the potential for application in decision support by providing interpretation aids, automatic analysis and situation assessment. In these applications, intelligent software agents automatically would assimilate the latest relevant data from sources such as sensors, intelligence reports, and human decision makers; and would provide plausible hypotheses about the current situation and forward the information to the warfighter (Shumaker, p.13, 1998).

IO requires that the knowledge practitioner make sophisticated distinctions between hierarchical levels of the cognitive process by which data and information contribute to effective decision-making. “Chief among these distinctions is between "awareness" (the lowest level of cognition), "knowledge," and "understanding." One can be "aware" of something but not know its specifics. Similarly, one can "know" something, even very well, but not "understand" its full implications, especially as they impact and are impacted by specific circumstances” (Rothrock, p.2 2004). A DNOC can provide the tactical warfighter all the information necessary to gain situational awareness and yet understanding still involves knowing why some events transpire or why enemy forces exhibit certain behaviors. Meaningful, relevant, and appropriate knowledge provides a basis of support in understanding the factors of time, space, and forces influencing events and enemy behaviors. Intelligent software agents should support information transactions that in turn aid the decision maker in converting their knowledge into understanding. To achieve understanding, one ascends the cognitive hierarchy that allows one to create strategy, align goals, monitor actions, shape and influence responses based on an understanding of how the enemy is thinking (JV2020, p. 29, 2000). The process of ascending the cognitive hierarchy toward understanding is illustrated in Figure 9. A coherent DNOC Human System Interface (HSI) consisting of visualization, association, and correlation can ultimately drive the decision-maker toward understanding.

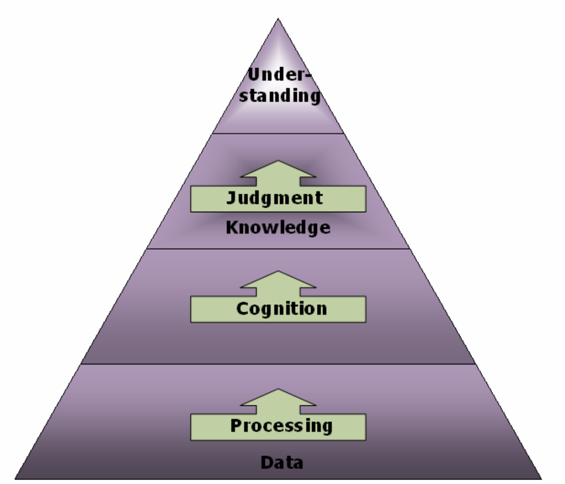

Figure 9. Cognitive Hierarchy. (From: FM 100-6)

The real power of intelligent software agents comes into its own if the DNOC system is able to transform the warfighter into an autonomous fighting node that is networked with manned/unmanned sensor-information systems which together form a fully distributed, cooperative battlespace C^2 system (Andriole, p.316, 1986). It is also the desire that these intelligent software agents operate effectively in situations where C^2 nodes may cease to function and where the degree of interoperability between participants may be severely limited, implying an inability to rely on centralized C^2 (Baciocco, p.211, 1986).

Another required capability is to design a DNOC that can determine the status of the decision maker’s cognitive processes and adjust the information available and the way it is being presented to avoid information overload. Improved information visualization displays will be required to present information to the decision maker in a variety of functionally useful forms. Pattern recognition or ambiguity software agents that take into account the nonverbal methods of communication like an adversary’s body language, aggressive behaviors, and physiological vital signs need to be developed. As software agents become more intelligent-like and autonomous, humans must understand what actions are being taken and the potential limitations these actions might create for the decision maker.

E. UTILITY

Social-technical engineering, properly applied to DNOC solutions, offers the possibility of alleviating the tactical warfighter’s informational burden by bridging the gap between the demand of the task and his or her cognitive limitations. Below is a list of a few characteristics that researchers feel should be incorporated into the ICT system design:

- Usability – International Standards Organization (ISO) Standard 9241 defines usability in terms of the effectiveness, efficiency, and satisfaction of a specified set of users for a specified set of tasks in a particular environment.
- Battle Ready – DNOCs must be designed for hostile environments. Battlefields are noisy, hot, cold, wet, dry, dirty and uncertain; therefore it is essential that it performs as expected—it must work every time! (Tyler, p.38, 1999)
- Common Vocabulary (Semantic Harmony and Syntactic Alignment) – Users prefer to have information displayed to them in familiar, inferable, and relevant operational terms—not insignificant architecturally-based terms (Hayes-Roth p.16, 2005). The cognitive performance of the decision-maker improves if the information is presented in meaningful content rather than in abstract symbolic form (Klien, p.39, 1993).
- Information Assurance – It must allow uninterrupted flow of rapid, reliable, and secure information directed to the warfighter’s organization (smart push),

> while allowing the retrieval of relevant and useful information from a variety of media (smart pull). It should have an alarm cueing function so that when performance degrades for any reason, the end-user and system are alerted (Kahan, p.37, 2001).

This list does not pretend to be exhaustive, but it focuses on the critical characteristics that are necessary to incorporate in the fundamental design of a DNOC system. Unfortunately, today's system architecting for majority of decision support systems is devoted to the technical aspects of system design; behavioral aspects are often overlooked resulting with an ineffective decision aid (Reneau & Blanthorne, p. 1, 1998).

As argued throughout this thesis, if the DNOC does not present the gathered data in meaningful and usable way, it has not served to reduce the warfighter's uncertainty. The concerns of operator familiarity, ease of use, and degraded performance pale in comparison to the information warrior's ability to create, protect, and maintain an accurate picture of the tactical battlespace. The DNOC must reduce friction and uncertainty of asymmetric warfare by providing knowledge, understanding and flexibility to the warfighter. Ultimately, this DNOC must enhance the collective and individual real-time understanding of the battlespace and never interfere with the "human" ability to completely command and control the IO process.

F. CONCLUDING REMARKS

DNOCs incorporation of effective and efficient ICTs has the potential to enhance situational awareness and accelerate SA into situational understanding. However, a technology driven approach has shown that increased informational processing and computational power does not guarantee improved decision-making. Instead a human-centered design approach is needed for the smooth and effective human-computer interface. The human-in-the-loop design approach attempts to optimize the human system integration, and allow the potential benefits of intelligent software agents to aid the warfighter's situational awareness through increased understanding. If we are to give credence to Alvin and Heidi Toffler's "Third Wave" of conflict (Arquilla & Ronfedlt, p. 14, 1997), asymmetrical threats will bring with them adversaries who will challenge the warfighter's decision-action cycles while making their own cycles increasingly difficult to penetrate. Knowledge practitioners must develop DNOCs that will help warfighters in making timely and relevant decisions based on their information needs, thereby accelerating tempo in an effort to get ahead and stay ahead of the decision action cycles of their adversaries. Future DNOCs should incorporate intelligent software agents that support the warfighters’ cognitive processes, not slow down their decision-making—the ultimate purpose should be to reduce…not increase uncertainty.

VII. DNOC DECISION SUPPORT ARCHITECTURE

A. INFORMATIONAL FRAMEWORK FOR DECISIONS

The TSDN team uses a decision support architecture that facilitates information quality and team collaboration on shared situational awareness and, eventually, innovative decision making and interdependent action. Good decision making takes information and a network of learning relationships between all members of a research team, and transforms this dynamic into knowledge. Figure 10 illustrates the DNOC's decision support architecture that includes organizational, operational, informational, and transactional decisions (Gateway Interface). The information flowing through the TSDN's hybrid wireless-mesh network is fused, analyzed, and disseminated to the DNOC's Common Relevant Operational Wall of Networking (CROWN). This, in turn, affects tactical situational awareness and understanding through the process of team collaboration.

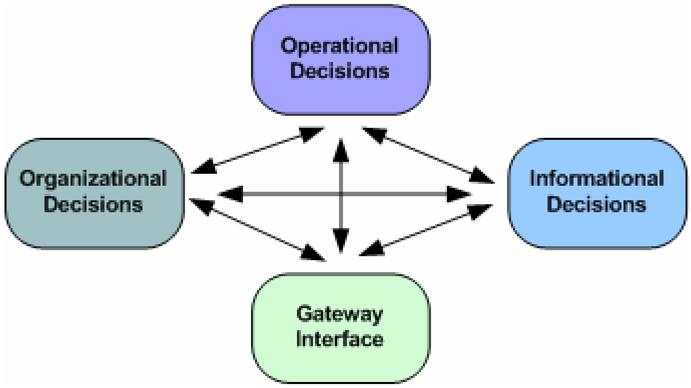

Figure 10. DNOC's Decision Support Architecture

1. Informational Decisions

TSDN informational decisions are those that are defined as situation assessment—primarily those concerning the situational evaluation of sensor to effector (shooter) behaviors and actions. Knowledge practitioners assimilate data into information and then process this information into useful knowledge so they can make a tactical decision about the current state of the environment. Due to the relative importance of informational decisions, a collaborative technology system must fuse, analyze and disseminate timely, accurate, and relevant information to the knowledge practitioner.

2. Organizational Decisions

TSDN organizational decisions include those that are related to the composition of tactical nodes; the command and control structure; and distribution of functions, roles, and tasks. The characteristic feature of organizational decisions is their orientation toward a comparatively broad range of situations. The essential qualities are the ability to adapt to dynamic and complex environments and the ability to remain stable with respect to extraneous influences.

3. Operational Decisions

TSDN operational decisions include all forms of decisions ranging from network management to tactical field activities. In particular, the determination and execution of the mesh network of sensor/effectors' purpose, goals, and mission objectives. Operational decisions also include harvesting the measures of effectiveness/performance/merit associated with each sensor/effector course of action.

4. Gateway Interface

It is incumbent that decision makers act as a gateway interface (experiment facilitator) to ensure effective integration of tactical transactions between manned and unmanned sensors/effectors. Many of the experiments associated with TSDN operations surround interoperability issues. It is imperative that decision makers leverage information to properly manage the interfaces that ultimately task the sensors/effectors.

5. Common Relevant Operational Wall of Networking

The CROWN is designed to align with the three coordination and cooperation decision domains—organizational, operational, and informational. The model, as illustrated in Figure 11, assumes TSDN collaboration is being employed; in which arrays of manned and unmanned sensors/effectors transmit data about the tactical environment to a central collection and fusion facility (DNOC) that ultimately disseminates visual information by use of the CROWN to DNOC watch team. The watch team, through pre-attentive cognitive processes, rapidly interprets the visual information they receive and collaborates with each other and geo-dispersed tactical units in order to improve everyone's shared awareness. The DNOC team's business processes include data collection and processing, fusion, analysis, and information dissemination. Inferences are drawn from patterns that tactical manned/unmanned entities exhibit.

The DNOC team extracts data from the sensors and processes this data into structured information in form of a CROWN. Three primary functions are performed: collecting tactical and environmental network data through the use of manned and unmanned sensors, including tasking these sensors to close gaps in data; processing data through fusion processes to produce the CROWN; and disseminating relevant information of the CROWN to tactical units. The CROWN contributes to the collaboration process in which shared awareness is transformed into shared understanding. The quality of the CROWN, therefore, depends on the AVMM system that facilitates rapid assimilation of TSDN information.

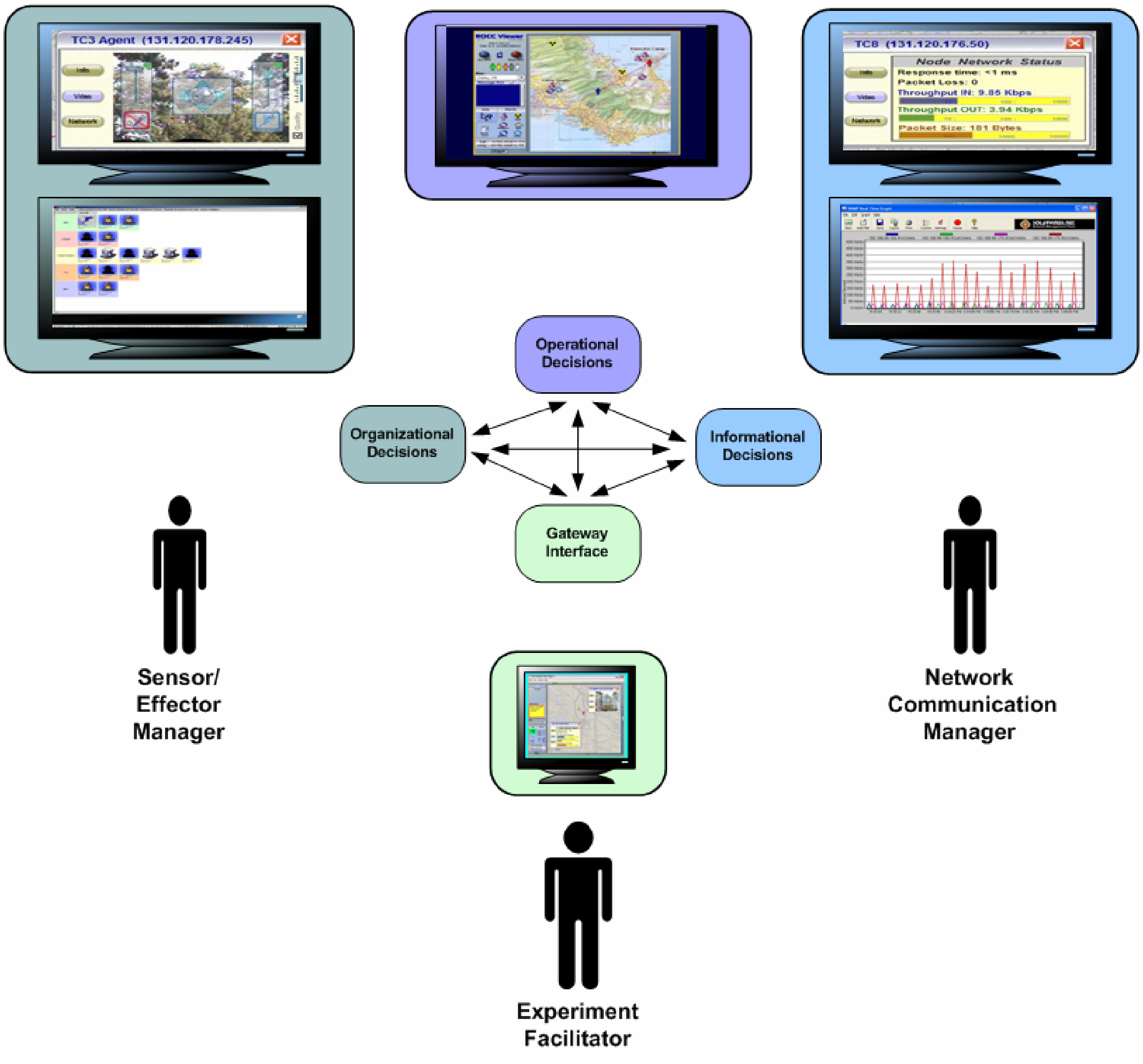

Figure 11. DNOC's CROWN

6. Shared Awareness & Understanding

The DNOC team must possess some degree of shared awareness to form a shared understanding, i.e. draw inferences from the information visuals presented to them and collaborate toward shared meaning. Network reliability and availability alone are not enough to ensure that the DNOC team obtains shared awareness and understanding. The informational, operational, and organizational processes must all be fused so that the team obtains the right information, at the right time, and in the right format.

This requires a more precise definition of situational understanding (SU). Situational understanding here builds on Hayes-Roth's Valued Information at the Right Time (VIRT): situational understanding is obtained when the operator receives enough VIRT and makes the proper use of it. SU, therefore, is the goal of the operator, and any information system that supports him (Hayes-Roth, p. 1, 2005). TSDN experiments should be designed in such a manner that the operator's SU can be measured and improved.

The definition of SU (above) is subjective and cognitive. Surveys, questionnaires and operator interviews would therefore be an invaluable way to measure SU at each TSDN field experiment (Hayes & Alberts, pp. 246-252, 2003). Such methods, if properly designed and executed, could allow a process of continuous improvement in SU over the course of the TSDN campaign of experimentation. These methods should not impede the conduct of research during individual TSDN experiments.

An informational framework would format VIRT and allow the operator to make proper use of it. It would also allow for ease of transmission. Informational frameworks can exist at many levels, similar to the Open Systems Interconnection (OSI) reference model. An informational framework that increases the operator's SU would meet several key criteria: it would clearly present information, provide a standardized format, transmit quickly, and eliminate unnecessary redundancy.

VIII. DNOC PROGRAMMATICS

A. PROBLEM AND SCOPE

> The future of warfare lies in the streets, sewers, high-rise buildings, industrial parks, and the sprawl of houses, shacks, and shelters that form the broken cities of our world. We will fight elsewhere, but not so often, rarely as reluctantly, and never so brutally. Ralph Peters

U.S. Expeditionary and Special Operations Forces (SOF) are deficient in critical capabilities to conduct Global War on Terrorism (GWOT) activities in urban environments. Particular issues involve:

- Lack of shared situational awareness with resulting potential fratricide, and the inability to navigate in environment containing "fog and friction"
- Lack of high-bandwidth communications at the tactical level, hindering tactical Coordination and Cooperation
- Urban clutter providing threat with high ground advantage, and ability to avoid detection by the tactical units who are engaging them
- Threat employing ambush techniques and improvised explosive devices (IEDs)
- Threat having "home field advantage" in and around urban environments

B. MISSION NEED

The DNOC initiative directly supports advancement of urban operations by providing accelerated improvements to tactical coordination and cooperation in urban environments. To increase the tactical warfighter's critical capabilities needed to fight the GWOT, the DNOC supports research toward developing a mesh network structure that provides dynamic and robust video, voice and data routing to tactically disbursed subscribers in mobile, wireless, and constrained environments. The primary purpose of the DNOC is to demonstrate and field-evaluate emerging and innovative technologies that will provide shared awareness through a Common Relevant Operational Wall of Networking (CROWN) to the tactical warfighter. It uses an open architecture construct to facilitate integration of the best components rapidly. The development of a tactical network topology of manned/unmanned sensors and vehicles (air/ground/maritime) networked with tactical warfighters will improve current intelligence, surveillance and reconnaissance (ISR) capabilities in urban environments. The DNOC's infostructure should ultimately support knowledge practitioners in developing and refining services (doctrine, tactics, techniques and procedures) with a baseline concept of operations for the use of such a network in a tactical environment.

C. OPERATIONAL REQUIREMENTS

The DNOC currently demonstrates communication and geo-positioning capabilities for use in restrictive and constrained environments that provide:

(1) Scalable, flexible, non-hierarchical, and robust wireless networks to enhance communication at all tactical levels involved in urban operations in urbanized terrain

(2) Integrated use of manned and various unmanned (air/ground/maritime) platforms to provide in-depth overlapping ISR coverage of critical areas

(3) Networked and arrayed sensor capability, dynamically linked with shared situational awareness agents that extends the tactical network awareness and provides integrated communications and a geo-location management framework

(4) Use of collaborative tools and information visualization devices to enhance ability to conduct highly coordinated combined ground activities using combinations of manned and unmanned systems

(5) Highly disseminated shared awareness and network management information among distributed tactical users

D. TECHNICAL CHARACTERISTICS

Distributed and collaborative networking among distributed tactical sensors and decision makers encompasses a wide range of significant technical characteristics that fundamentally support TSDN's applied research initiative (Bordetsky, et al. p.2, 2003). The DNOC deals with and accommodates a wide variety of technical characteristics that include:

- Distributed computing over a robust, ad hoc, dynamic wireless network
- High volume throughput of continuously refreshed data
- Mult-Sensor Fusion—data fused from a wide range of disparate systems and sensors
- Fault tolerant system in which, at any given time, it is clear what nodes are available within the network

- Wide dynamic range of processing and database collection loads
- High reliability, availability, and survivability requirements
- Asynchronous, event-based low latency response
- Network security and accessibility
- Decision and collaborative support—a network capable of supporting collaboration decision making
- Information analysis and summary of enormous amounts of data from the mesh network on the basis of end-user needs

E. FUNCTIONAL PERFORMANCE

Throughout a system’s design process, critical design decisions are often made by stakeholders familiar with the technology involved but who do not fully understand how the tactical operator will employ the system. Consistent and thorough collaboration with potential system end-users are necessary to drive developer’s efforts; particularly during the design phase. The DNOC initiative and its supporting collaborative applications represent a major step forward in accelerating the tactician’s shared situational awareness for increased understanding of the tactical environment. To facilitate a robust management of robust visual display information, development and design processes must have more than good intentions; these processes must have end-user involvement and commitment. Therefore, the DNOC AVMM system should support tacticians in:

- Rapidly recognizing, understanding, and exploring the implications of changes in the tactical battlespace
- Accelerating the use of “pre-attentive cognitive processing” that directly links tactical battlespace perceptions, decision making, and execution
- Sustaining a shared context collaboration environment among members of knowledge-practitioner teams located at multiple operating locations

The objectives are to provide:

- Shared understanding of the network and tactical situation
- Scaleable, flexible, and tailorable information visualization
- Advanced decision support and knowledge management tools
- Distributed decision-making, collaboration, information management, and dissemination among users

- Leveraged value-added information through modeling work processes of user-specified and dynamic network QoS and CoS level needs

F. INFORMATION FLOW ARCHITECTURE

As represented in the informational flow architecture in Figure 12, the system requirements are decomposed into hierarchical modules and horizontal functional flow decision elements to support the DNOC's tactical information management process. Each function is decomposed into lower-level sub-functions or missions (Kossiakoff & Sweet p.381, 2003). Below in Figure 12 is top level information flow architecture that is color coded to align to Figure 13 which depicts the functional and physical layout of the DNOC.

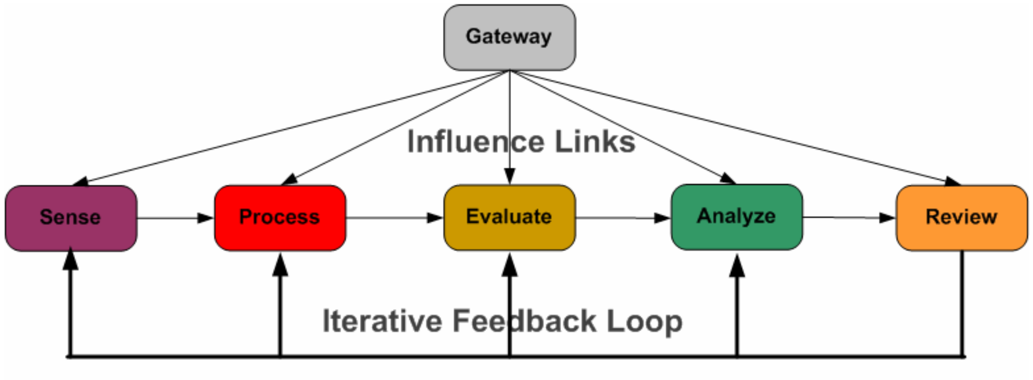

Figure 12. DNOC Top Level Information Flow

Figure 13. DNOC Function & Physical Layout

In order to fulfill tactical mission requirements, decomposition is iterated in Figure 14 until allocation to a particular system(s) or system element(s) is complete. As for the performance requirements, network and collaboration support requirements within the hierarchical relationships are utilized in the construction of parent-child relationships during specification of task manager objects (the primary structure of the human system interface). Advantages inherent with this architecture include a well-structured tactical battle rhythm, modularity for easy upgrades, and a highly interoperable communication and coordination design

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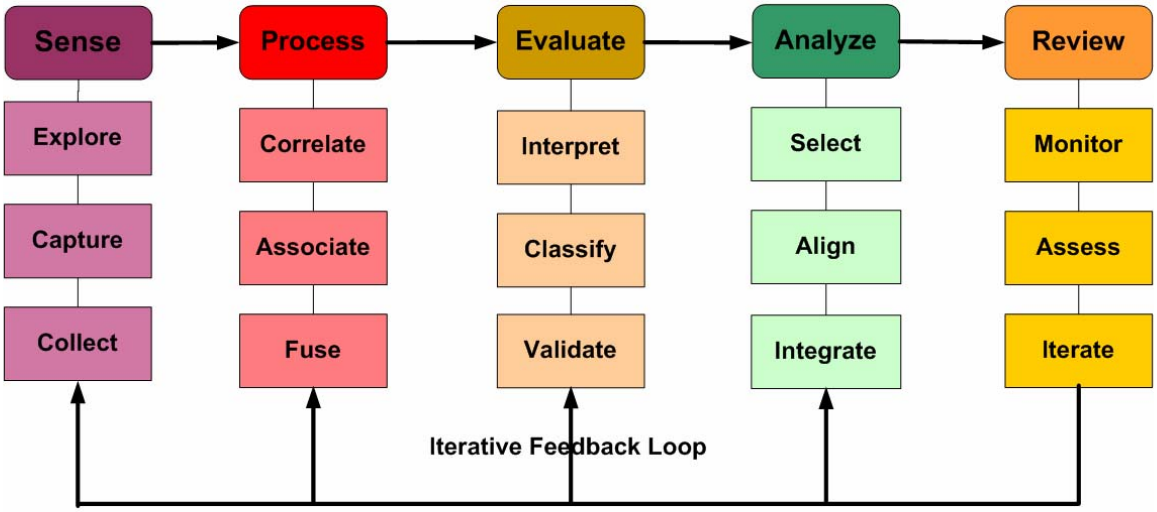

Figure 14. DNOC Information Flow Architecture – Functional Class Decomposition

G. PERFORMANCE BENCHMARKS

The DNOC project was conducted aggressively in three phases, lasting 3 months, 6 months, and 9 months. The funding for phases was entirely contingent upon meeting system-level performance capabilities established during the concept development and technical requirements phase.

Benchmark I – Remote Dependent Autonomy: The DNOC must demonstrate that coordinated autonomy can be achieved by a Tactical Operations Center (TOC) located at a remote area outside of a restrained or constrained urban area. This required netted tactical operations in a small pseudo-urban site (Camp Roberts) inside an area containing small, scattered, and well-known infrastructures serving as obstacles. The system had to accomplish the simultaneous tasks of persistent wide-area surveillance and the ability to dispatch a sensor to a single effector-designated point for a rapid-reaction close-up look.

Benchmark II – Collective Independent Autonomy: The DNOC system must manage diverse assets such that they achieve the collaborative task of maintaining a moving area of responsibility (AOR) around a moving ground target (e.g., to follow a suspect terrorist, or to maintain a moving zone of blue-force ISR).

Benchmark III – Tactical Interdependent Autonomy: Through continued and iterative consultation with the tactical operators, the DNOC program must develop, implement, and experiment with tactical commands to achieve seamless system integration and interoperatability. The tactical scenarios for the DNOC should illustrate network-centric coordination and cooperation capabilities. Finally, at a minimum, the DNOC must demonstrate the system's ability to manage multiple users with conflicting priorities; demonstrate robustness to sensor/effector attrition; and implement a secure, rapid and reliable networking infostructure to multiple points.

H. PROJECT SCHEDULE

The DNOC team committed to an aggressive concept and technical development schedule to meet the quarterly needs of the NPS-USSOCOM Cooperative Experimentation Program. FY05 focus has been on two USSOCOM projects; the Light Reconnaissance Vehicle (LRV), and the Joint Manned-Unmanned System Teaming effort. Strict adherence reviews and reports allowed for a smooth transition through concept development to system demonstration and successful operational testing with the first operational DNOC equipped on time and within budget. The Gantt chart below in Table 1 illustrates a six month aggressive project schedule.

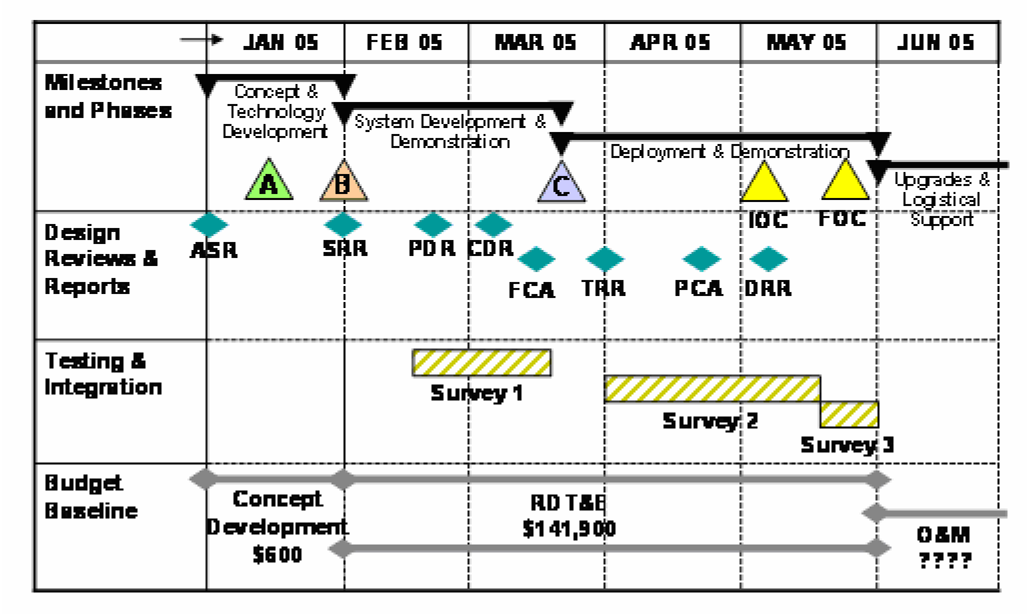

Table 1. DNOC Project Schedule

Prior to each field experiment, a required test requirements review will take place to develop testing baselines and metrics for how well the operator and technology requirements have been met. As construction was completed, a physical prototype configuration audit determined if there were any human systems integration unknowns. Follow-on testing and evaluation occurred following TNT 05-2 and TNT 05-3 experiments. During design, build, and implementation phases, the DNOC team along with its current SOCOM sponsor was able to develop and refine requirements necessary to complete the DNOC within five months.

I. BUDGET ALLOCATION

The DNOC team was awarded a total of $142,500 from the Center for Defense Technology and Education for the Military Services (CDTEMS). CDTEMS funding was provided to NPS through a congressional plus-up.

J. MANAGERIAL ISSUES

Using the DNOC’s top-level Program’s Work Breakdown Structure (WBS), depicted in Figure 15, to define every project phase, task and sub-task, the DNOC team ensured no factor was overlooked. And, rather than scheduling only materials and capacity, the WBS allowed the team to schedule human resources as well—so the

DNOC's sponsors were able to see planned and firm demand for all active and anticipated projects and all resources needed to complete them.

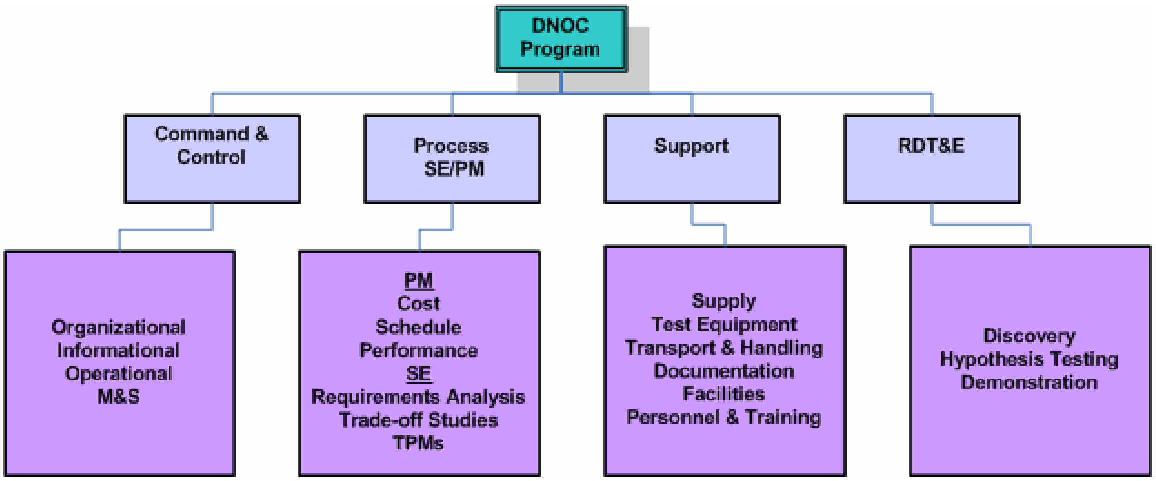

Figure 15. DNOC Top Level WBS

K. PROJECT CHALLENGES

As a significant sponsor of TSDN research, USSOCOM has particular interest in a mobile "information system" that is robust, interoperable, stable, and with strong connectivity. In order to achieve this flexible network, several back-up communication relay stations should exist. In the event a relay should fail, a back-up can be accessed to maintain connectivity among the critical nodes in the network. Proper planning would require the Network Operations Center (NOC) at NPS and the DNOC's Tactical Operations Center (TOC) at Camp Roberts to be operational a couple weeks before actual experimentation begins to ensure close coordination between the respective field experiment principal investigators. This pre-testing would also prevent last minute reorganization of assets. Other challenges inherent in this program are to demonstrate performance capabilities by:

1) Increasing efficient pre-attentive cognitive motor skills by integrating and managing information at the right level of abstraction to meet end-user's needs
2) Presenting the user with accurate information when the information sources may have substantial errors and/or suffering from gradual degradation
3) Integrating information from large numbers of dynamically changing, inconsistent, heterogeneous sensors, collaborative human and software agents

4) Providing rapid, accurate, and secure automated site monitoring using imagery from manned/unmanned sensors

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IX. WARFIGHTER MEETS ACADEMIA

A. TSDN - RELEVANT USE CASE

1. Innovation

Innovation is a key to enabling the United States to maintain military superiority in this era of technology. During the Cold War, the military was able to display its prowess through an arms race with the Soviet Union. The goal was easily established where the country with the most arms won. Today, however, the quantity of military equipment is not nearly as important as the quality of the technology used to fight today's conflicts. Development and implementation of new technologies, however, is only beneficial to the warfighter if he or she can use it effectively on the battlefield. Therefore, it makes sense that the warfighter should have a role in the development and implementation of new and emerging technology.

TSDN operations is a relevant 'use case' for proving the necessity of the warfighter's role in military innovation. Networking and collaboration requires more than just the latest technology, it requires increasing the warfighter's ability to capture the data, fuse the data into useful information, forge the information into knowledge, and then gain an understanding of this knowledge before making a decision. It seems obvious that the warfighter should play a pivotal role in the development of technology that he or she may use when facing the adversary, but is less obvious that the warfighter should be involved in the theory and design of said technology. There are benefits to involving the warfighter in the theoretical conceptualization and design of new technologies. Many military officers bring with them strong academic backgrounds in the field of engineering and science as well as recent military operational experience, and have a vested interest in developing useful technology that they will employ when they are sent back to the battlefield.

2. Academics

The military spends an impressive amount of money educating its future officers so that their talents can be cultivated for use by the military service. While studying in college, these future officers are challenged with thinking creatively and seeking innovation, however, once they are thrust into the military environment, they must shift to a highly disciplined lifestyle that encourages conformity and responsiveness. Herein lies the paradox between the military establishment and academia that initially makes the blending of the two institutions appear to be in conflict. Whereas the military expects discipline, conformity and responsiveness; academia breeds innovation, flexibility and creativity.

As the scientific and technical capabilities of the armed forces continually evolve, it is increasingly necessary to maintain a corps of officers and other leaders who have maintained the mental agility that permits them to think creatively, but who are also able to meet the demands of military lifestyle. These officers are prepared intellectually to harness innovation so that our military is prepared to conduct and sustain decisive operations (OFT, p. 14, 2004). The military needs this cadre of intellectuals to understand the systems and the technology they may potentially operate in the future. The concept of the system extends beyond a particular platform, and into the realm of the battlespace. Understanding the technology, and the role of that technology in the tactical and operational levels of battle, will give decision makers useful, high quality information.

B. OPERATIONAL EXPERIENCE

When a warfighter enters academia he or she brings real world military experience. In developing technology this experience provides a common sense approach to new systems. Members of the TSDN team bring many years of military experience together with a desire to learn and understand more about the technology they used in the operational arena to create a user-friendly coordination and cooperation center (i.e., DNOC).

1. Command

Assuming command is perhaps one of the most significant benefits of this sort of education. Command, in this sense, is not defined by the Uniform Code of Military Justice (UCMJ) definition of command. Rather, the warfighter, who is often a mid-grade officer, is given the opportunity to ‘deploy’ an idea or theory into a sea of discovery and invention. The warfighter is, at times, challenged to lead a team through different phases of the study. This requires the warfighter to have vision and depth of understanding that reaches into the theoretical aspects of present and future technology. Warfighters are challenged to think creatively and freely to outsmart a potential enemy weapon or sensor.

To accomplish this, the warfighter must develop understanding of the research environment that surrounds his or her research and develop an intimate understanding of challenges and potential research opportunities. A reward of academic accomplishment is that the warfighter has a voice in his or her ability to fight and win wars.

2. Tolerance for Risk/Establishing Trust

Unfortunately, the cultural aspect of the military creates, perhaps, the most significant obstacle to transformation. Presence of this characteristic is due, in part, to a low tolerance for risk that is still common among senior military leaders. In an academic environment, a warfighter can fully extend his or her imagination to create and implement controversial technologies with minimal risk to life, limb, or career. The TSDN team is able to experiment with their ideas and theories about improvements or innovations for coordination and cooperation on the battlefield. A benefit to operating in the field of academia is the ability to conduct trial and error experimentation and the acceptance of possible failure.

Established as a learning organization, the ad hoc teams of TSDN used a ‘bottom up’ approach to coordination and cooperation. Individuals of the TSDN watch teams designed the collaborative infostructure based upon the need of the tactical situation. Partnership between the TSDN watchstanders was lead by research facilitators who encouraged teamwork as the focus of this organization. Each of the watchstanders was responsible for understanding the guidelines or ‘facilitator’s intent’ pertaining to the experiment/scenario so that they were able to perform effectively and efficiently as a team.

3. Modularization Concept

The modularization concept of the TSDN required that dynamic organizational learning had to take place each time watchstanders came to the watch floor. Unlike typical watchstander rotation were one watchstander simply ‘relieves’ another watchstander, the TNT modular watchstander, depending on the situation, assumed an entirely different role when he or she came to the watch floor.

Effectively employing the modularization concept requires organizational and contractual trust. Organizational trust is essential to the development and utilization of ad hoc teams in an operational military environment. Most basically, the commander must trust that the watchstanders have adequate training to operate their equipment and understand their role in the particular situation. In the professional bureaucracy, trust is manufactured through standardization of skills, behaviors, and training. The hierarchical command structure acts as "prosthesis for trust" when an organizational chart clearly outlines duties and responsibilities, or in other words, who you should trust and who you don't have to trust (Bennis, Spreitzer, & Thomas, pp. 66-70, 2001). A commander's intent is generated, specifically outlining what is expected of subordinates. A rigid chain of command is established to facilitate compliance. During a ship's training cycle for deployment, for example, outside activities monitor a ship's TT&P and maintenance to ensure that the ship is following naval doctrine and standards. Commanders and watchstanders will trust that the information passed to them is accurate and relevant because they each trust the training and guidelines established by the military institution. Simply put, organizational trust in the military system assumes that adequate training has taken place so that the commanders and watchstanders know their jobs.

Secondly, for a modular team to efficiently integrate into the battle scenario a form of contractual trust must be present within the organization. The commander must make a form of contractual trust with the incoming modular team. He or she must understand what the modular team brings to the collaboration infostructure. An agreement of sorts must take place where the commander understands what services the team brings to the battlespace and the team members understand what services they are expected to perform. Additionally, a commander cannot expect the implementation of a new modular unit will cause the battlespace to have less fog or friction unless the capabilities of the modular unit are designed to detect and engage the threat and will truly give the commander better situational awareness.

The commander must measure his or her ability to trust. Self reflection is necessary because if a commander is unable to trust in his or her subordinates then the system is destined to fail. Micromanagement is a failure of leadership in any kind of organization. Highly networked organizations are particularly vulnerable to micromanagement due to the relative ease that commanders have to information on the battlespace. Operating in a networked environment places commanders within an Internet Protocol (IP) address reach of soldiers on the front lines. Micromanagement may help a commander to feel more ‘in control’ of a situation; however, he or she is actually hindering the ability of the operator to carry out the assigned mission due to the added requirement of having to respond to a commander. Therefore, for network operations to operate as designed, commanders must take the time to measure and assess their ability to trust their subordinates.

A final goal of networks is building a culture of trust. Once commanders and operators establish a trust based work environment, the capacity of the technology will be maximized. Advancing technology and implanting it into the battlefield also requires that a cultural change takes place where the crutches of hierarchy are replaced by a sturdy foundation of trust.

TSDN is an exceptional platform to study the different forms of trust that must take place when developing and engaging ad hoc teams. The modularization concept behind the design of the TSDN operations is a good test platform for commanders who must learn to integrate the modularization concept into their individual commands (i.e. LCS). TSDN research should also examine the ability of a military command to, organizationally, handle Network-Centric type operations.

One of the difficulties of Network-Centric Warfare (NCW) is the conflict between the military hierarchical design and the networked organizational design that is required to maximize the available technology and transform the military into the information age. The military and academic blend for achieving success in applied research was achieved during the recent TSDN field experiments. Researchers witnessed that the military personnel provided operational experience and a clear desire for responsibility and accountability. Framing what needs to get done is the very essence of military operations and ensuring unity of effort. If not, the military is wasting time and resources, not to mention risking people’s lives needlessly for actions that may or not be necessary for achieving success.

C. TSDN EXPERIMENT (TNT 05-3)

1. DNOC Watch Team

A good blend of military and academia working together was witnessed during the TSDN Experiment conducted 16-27 May 2005, in which the TSDN operational framework outlined in this thesis was implemented. Although, there were data collection efforts and DNOC watchstanders in previous experiments, there were three major differences between this experiment and the last set of experiments.

First, the roles and responsibilities, as shown in Figure 16, of the watch team were laid out prior to the commencement of the experiment.

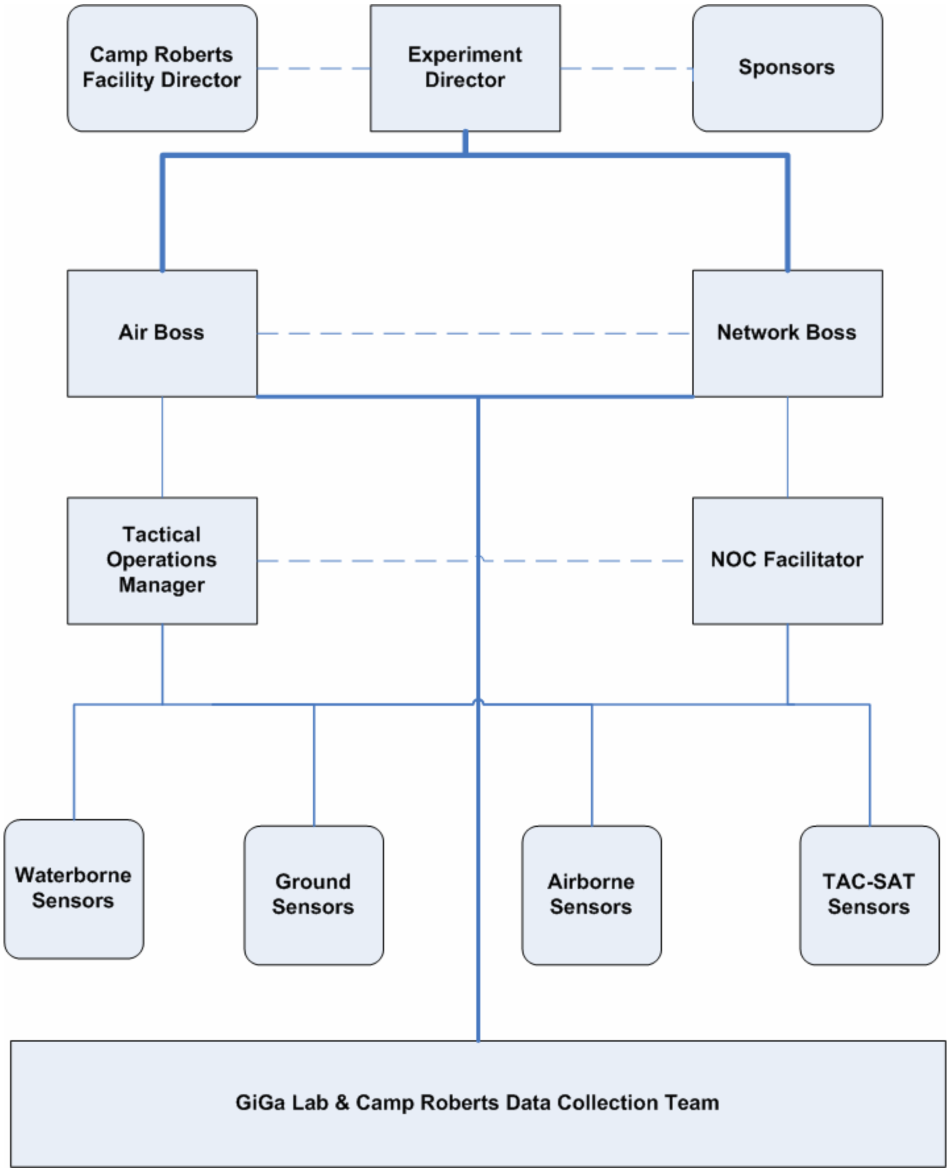

Figure 16. Coordination & Cooperation Organization Chart

The watch team fully understood what their role was in the big picture of the experiment. A Tactical Operations Manager was specifically told what tools he was responsible for and what events needed to be coordinated and logged. The NOC

Facilitator was told what IP addresses and nodes were required to be managed and observed. The Data Collection Team was told what data needed to be captured and what nodes needed to be observed with the SA monitoring tools. There in fact were no CONOPs or SOPs delineating responsibilities, just a clear dynamic data collection strategy, as shown in Figure 17 that guided the knowledge practitioners' efforts.

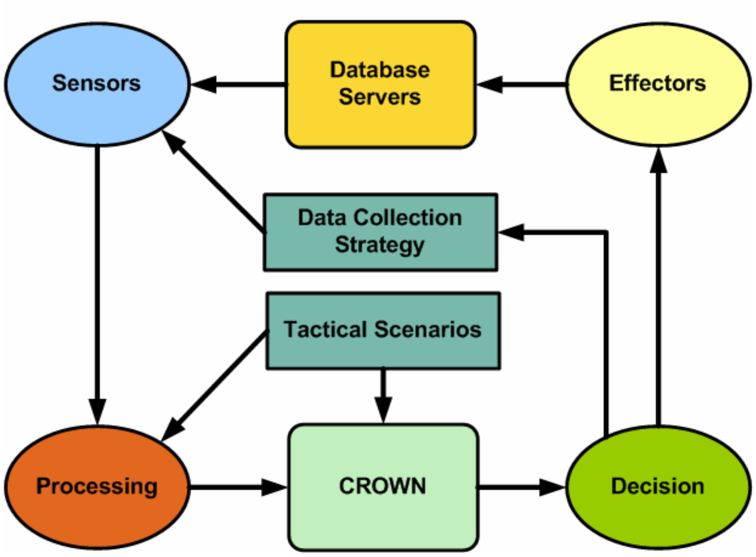

Figure 17. Dynamic Data Collection Strategy. (After: JWARS)

By clearly stating what roles were necessary, the watch team members were able to conduct the experiment without the Network and Air Boss having to focus and monitor the screens themselves, thus allowing them the ability to maintain the global view of the experiment.

Second, the team already established an organizational trust and loyalty to each other and to the TSDN organization. Previous teams were students from various Information Systems Technology (IST) classes that were thrust into the experiment with little to or no regard of what the experiment was to accomplish. In this experiment, the DNOC watch team consisted of students who were involved in the TSDN's day-to-day operations from the pre-experimental planning, tasking, and then execution—it was their organization and they wanted to support it.

As a final note, when introducing the variables of accountability and responsibility and clearly delineating these to all the watchstanders, the results were impressive. The DNOC's watch team infostructure was able to collect the right data, address the situations decisively, and maintain the common operational picture, thereby encouraging dynamic organizational learning. The fact that organizational trust had developed between students and faculty fostered a sense of empowerment and belonging among team members. This sense of empowerment allowed the students to feel safe in proposing innovative solutions and dynamically adapting to the environment without fear of reprisal for violating written baseline standards. This dynamic adaptation to the changing environment is the very essence of military Network-Centric Operations and was achieved during this phase of TSDN experimentation.

X. RECOMMENDATIONS & CONCLUSIONS

A. LEADERSHIP & TRANSFORMATION

> Any military service which tries to separate its fighters from its thinkers is likely to finish up with cowards doing the thinking and the fools doing the fighting. - British General

In order for the DoD to fully embrace the age of military transformation, a cultural change must take place that reflects the characteristics of the Information Age. Senior leadership must set the example by fostering innovation and adopting information age technologies and concepts. Leaders who have a conceptual understanding of the technologies that they are promoting will more closely identify with the capabilities and limitations of the war fighting mechanisms. These leaders will generally develop a strong sense of trust in good technology because of the depth of understanding of the system (Free, p. 58, 2005). This does not imply that the military should send senior leadership through graduate level engineering programs; rather investment in the education of mid-grade officers should be considered as an investment in the future because these officers will have the technical knowledge and operational experience to make informed decisions. Additionally, this does not imply that military officers should become operators of individual components (i.e. GCCS) in the network. What is implied is that educating officers in theoretical and technical engineering and sciences coincides with the transformational spirit of OSD.

A positive consequence of having a cadre of individuals with a depth of understanding of various aspects of military technology is an increased tolerance for risk. As seen in daily life, individuals who do not adequately understand a complex concept are less willing to experiment with the related technology. A transformational military force must undergo experimentation to discover innovative systems, more efficient business practices, or extend the capabilities of existing technology. When the warfighter is participating in the operational arena, he or she is often occupied with the daily challenges of life in the battlefield. However, by taking the warfighter out of the battlefield, the warfighter is able to devote attention to experimentation and disruptive innovation that is so badly needed in the military system. Unfortunately, the cultural aspect of the military creates, perhaps, the most significant obstacle to transformation. Presence of this characteristic is due, in part, to a low tolerance for risk that is still common among senior military leaders. In an academic environment, a warfighter can fully extend his or her imagination to create and implement controversial technologies with minimal risk to life, limb, or career.

B. TRUST

The warfighter also benefits from assuming advanced academic studies because of the vested interest that he or she has for useful technology out on the battlefield. Eventually, the warfighters will find themselves back on the front line and at the mercy of the advances of technology. When the warfighter goes back to the battlefield and is required to interface with technology, it is plausible to believe that the warfighter with a depth of understanding of the system will develop trust in the technology that is providing crucial information to fight the battles. The warfighter who has achieved this level of conceptual understanding about the way technology functions will, most likely, be more willing to trust the information from that technology, than the warfighter who fails to develop this conceptual understanding.

C. INNOVATION

How does academia benefit from the warfighter? Academia is provided with priceless operational experience and a generally common sense approach to the true nature of war. The fog and friction of war can not be adequately modeled by an equation or a physical law. The most advanced technological capability is useless unless the warfighter can interface with it and derive the necessary information to make decisions. The warfighter ensures combat effectiveness.

At the same time, academia allows the military the opportunity to collaborate, to realize that no one person is an island, but part of larger continent. In a professional bureaucracy, generally innovation is not rewarded unless the outcome is extremely favorable to the organization. Academia reminds the military that innovation should be embraced even if the outcome only benefits the organization in the short term. After all, innovation of itself is a long term benefit.

As the scientific and technical capabilities of the armed forces continually evolve, it is increasingly necessary to maintain a corps of officers and other leaders who are prepared intellectually to harness these innovations and apply them so that our military is prepared to conduct and sustain decisive operations. The military needs this cadre of intellectuals to understand the system in which the technology operates. The concept of the system extends beyond a particular platform, and into the realm of the battlespace. Understanding of the technology, and the role of that technology in the tactical and operational levels of battle, will give decision makers relevant, high quality information.

Ultimately, the premise behind TSDN research is that it is an opportunity for the warfighter to interface with innovative and emerging technologies. In the spirit of having a campaign of experimentation to completely evolve a network-centric force, the warfighter must be included in every step of the theoretical aspect. There are two added benefits to taking this approach: 1) the emergence of rapid and remote experimentation to dynamically support and enhance efforts during real world military operations, and 2) when the warfighter becomes operational again, he or she will truly understand the network-centric and social–technical systems that must be used to create a decisive warfighting advantage.

D. DNOC OBSERVATION & OVERVIEW

As observed in TNT 05-2 and 05-3, researchers were able to complete their experiment set-up faster through the plug-n-play feature of the DNOC, thus increasing collaboration and allowing more time to conduct experiments. With relative ease and speed, the knowledge practitioners were able to display and view any analog and/or digital video output. Exploiting hybrid wireless-mesh technologies and operating within the constraints of pseudo-tactical scenarios, TNT participants achieved reasonable situation awareness (SA) of network actions and behaviors. The DNOC watch team configured and displayed the performance actions, behaviors, and the states of the hybrid wireless-mesh network with little difficulty. However, there was a risk of visual information overload due to the glut of aggregated network performance, configuration, and fault management tools (a partial list includes AirMagnet, SolarWinds, AiroPeek, and OpNet). Throughout the DNOC's life-cycle, its visual information displays should be incrementally improved to enhance the end-user's pre-attentive cognitive processes and illuminate key decisions made through collaborative teamwork. The issue then becomes how to measure information’s impact within the realm of human cognition and gauge overload.

APPENDIX A: DNOC FLOOR PLANS

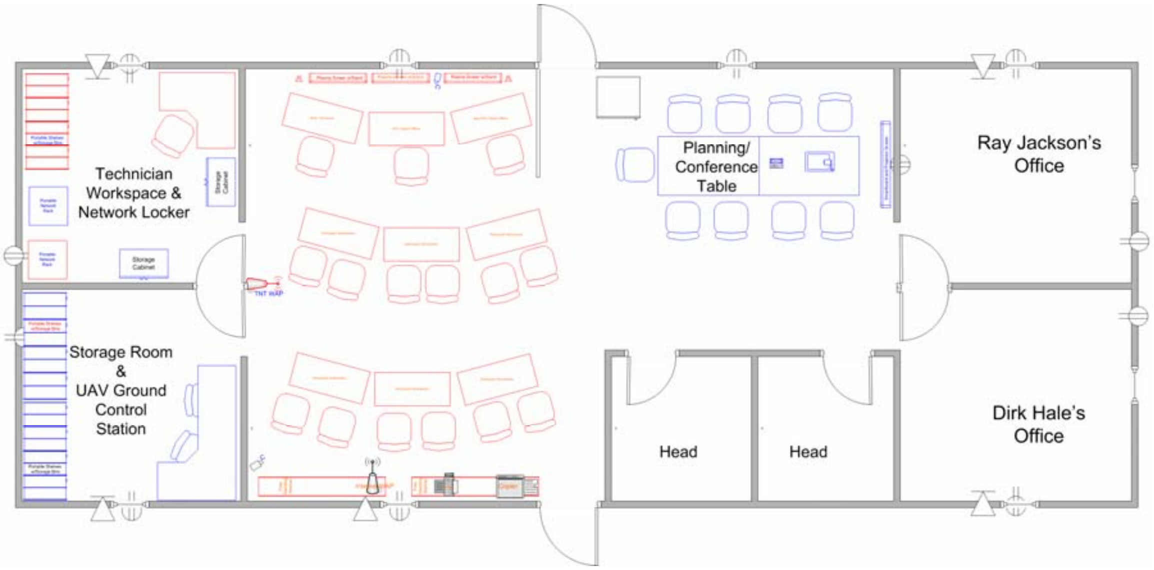

Figure 18. Working Floor Plan

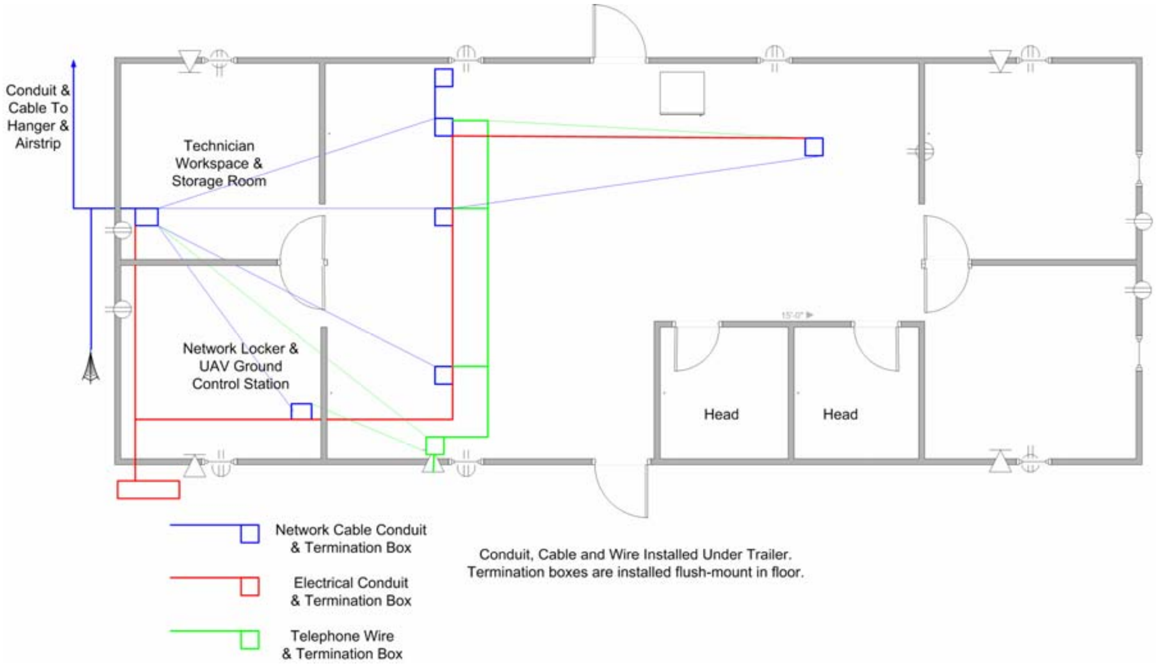

Figure 19. Under Floor Conduit Layout

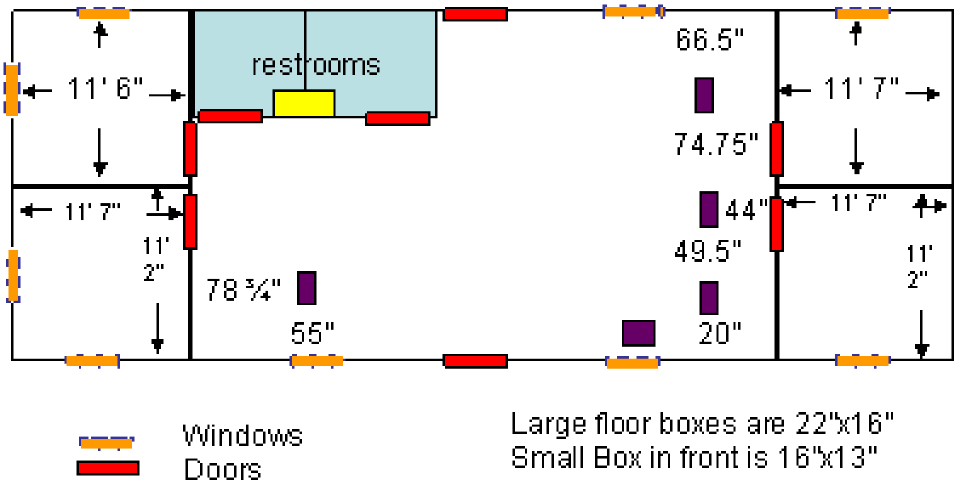

Figure 20. Above Floor Panel Box Layout

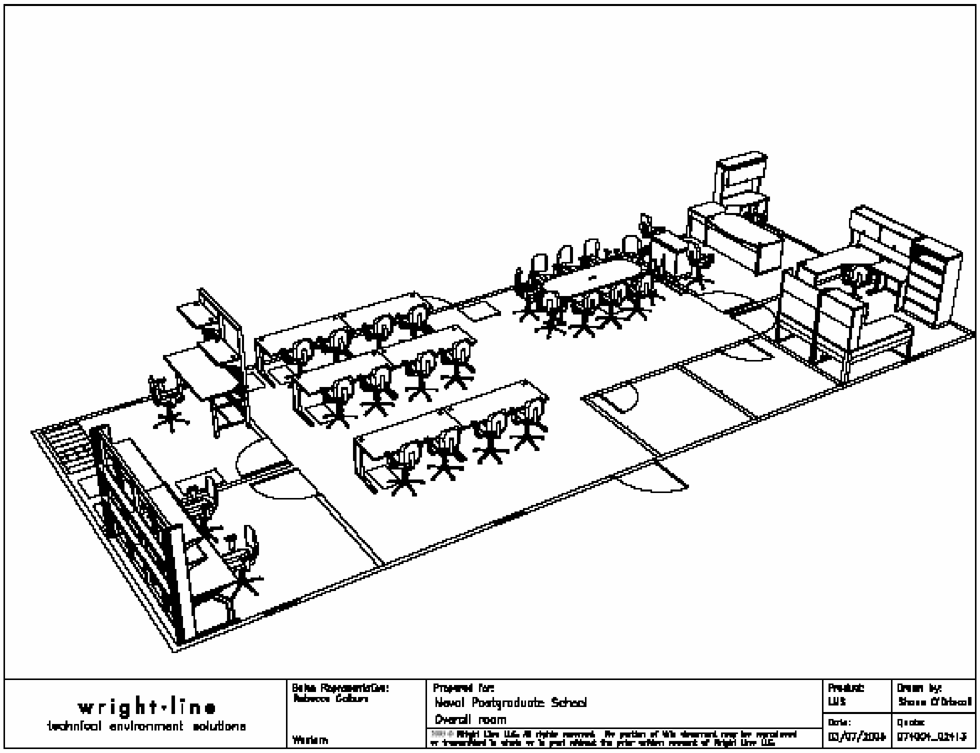

Figure 21. Furniture Layout. (From: Wright Line)

APPENDIX B: DNOC 3D VIEW

Figure 22. 3D Room Layout. (From: Wright Line)

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APPENDIX C: DNOC PICTURES

Figure 23. DNOC’s Supporting Infrastructure

Figure 24. Dynamic Collaboration 1 - DNOC

Figure 25. Dynamic Collaboration 2 – DNOC

Figure 26. Dynamic Collaboration 3 - DNOC

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