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THESIS

AN ANALYSIS OF COLLABORATIVE TECHNOLOGY ADVANCEMENTS ACHIEVED THROUGH THE CENTER FOR NETWORK INNOVATION AND EXPERIMENTATION

by

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December 2008

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The primary focus of this thesis is to produce an analysis of collaborative technology advancements experienced through the experimental cycles which the members of the Naval Postgraduate School Center for Network Innovation and Experimentation (CENETIX) participate. These experiments, which include Maritime Interdiction Operations (MIO) and Tactical Network Topology (TNT) scenarios, have advanced a great deal since their inception and there is a need for a detailed study into which changes have produced the greatest benefits to NPS and our partners.

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AN ANALYSIS OF TECHNOLOGICAL ADVANCEMENTS ACHIEVED THROUGH THE CENTER FOR NETWORK INNOVATION AND EXPERIMENTATION

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Submitted in partial fulfillment of the
requirements for the degree of

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The primary focus of this thesis is to produce an analysis of collaborative technology advancements experienced through the experimental cycles which the members of the Naval Postgraduate School Center for Network Innovation and Experimentation (CENETIX) participate. These experiments, which include Maritime Interdiction Operations (MIO) and Tactical Network Topology (TNT) scenarios, have advanced a great deal since their inception and there is a need for a detailed study into which changes have produced the greatest benefits to NPS and our partners.

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LIST OF ACRONYMS AND ABBREVIATIONS

3G	Third Generation Mobile Telephony Standard
AAR	After Action Report
AO	Area of Operations
(x)bits	Bits per Second (K: Kilo, M: Mega, G: Giga)
BFC	Biometrics Fusion Center
BFT	Blue Force Tracker
BO	Boarding Officer
BP	Boarding Party
BV	Boarding Vessel
C^2	Command and Control
C^4	Command, Control, Communications, and Computers
CBRN	Chemical, Biological, Radiological, Nuclear
CENETIX	Center for Network Innovation and Experimentation
CONUS	Continental United States
COP	Common Operating Picture
COTS	Commercial Off-the-Shelf
CR	Camp Roberts
DoD	Department of Defense
EMIO	Extended Maritime Interdiction Operation
FBI	Federal Bureau of Investigation
FEP	Field Experimentation Cooperative
GGB	Golden Gate Bridge
GHz	Gigahertz
GIG	Global Information Grid
GPRS	General Packet Radio Service
GPS	Global Positioning System
GWOT	Global War on Terrorism
HDSPA	High-Speed Downlink Packet Access
HQ	Headquarters
HVT	High Value Target

IM	Instant Messaging
IP	Internet Protocol
ISR	Intelligence, Surveillance, and Reconnaissance
JSA	Joint Situational Awareness
LAN	Local Areal Network
LBNL	Lawrence Berkeley National Laboratories
LLNL	Lawrence Livermore National Laboratories
LOS	Line of Sight
LRV	Land Reconnaissance Vehicle
MHz	Megahertz
MIMO	Multiple Input Multiple Output
MIO	Maritime Interdiction Operations
MU	Maritime Unit
NCW	Network Centric Warfare
NOC	Network Operations Center
NUC	Nuclear
NPS	Naval Postgraduate School
NY	New York
NYC	New York City
OFDM	Orthogonal Frequency Division Multiplexing
PANYNJ	Port Authority New York New Jersey
PDA	Personal Digital Assistant
QLR	Quick Look Report
RAD	Radiological
RHIB	Rigid Hull Inflatable Boat
SA	Situational Awareness
SFPD	San Francisco Police Department
SME	Subject Matter Expert
SMS	Short Messaging System
TNT	Tactical Network Topology
TOC	Tactical Operations Center
TV	Target Vessel

URL	Uniform Resource Locator
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
USCG	United States Coast Guard
USDOE	United Stated Department of Energy
USSOCOM	United States Special Operations Command
USV	Unmanned Surface Vehicle
UWB	Ultra Wideband
VC	Video Conference
VHF	Very High Frequency
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
WiFi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access
WMD	Weapons of Mass Destruction
YBI	Yerba Buena Island

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There are no words to express the appreciation I have for my best friend, my confidant, and my sounding board, my lovely wife, Amber. Without your infectious drive to make our life better and to pull me through the tough times I would be a shell of the man I am today. To my little buddies, Samuel and Chloe, your love is the reason the stars shine so brightly in the night sky. Thank you all for sharing this journey with me.

I would like to thank Dr. Bordetsky for your guidance and support, but most of all for your unwavering friendship. Through my trials here at NPS you stood beside me offering encouragement and compassion, for which I will forever be grateful.

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I. INTRODUCTION

> *In military operations, information has always been every bit as vital as fuel or ammunition in achieving favorable outcomes. Today, the need to reduce decision timelines highlights its importance. The Navy postulates that network centric operations will enhance the effectiveness of combat systems by allowing commanders to mass effects from great distances. At issue is verification of this assumption.*
>
> *Perry et al. (2002)*

A. BACKGROUND

There has never been a time in written history where technological advances have come at humanity at such a blazing speed. It is for this reason that the United States military and those directed to defend the homeland must develop methods for communicating faster and more securely than ever thought possible. The possibilities for our enemies, both foreign and domestic, to utilize newer and cheaper technological advancements against us in order to do us harm grow on a daily basis and our sheer size determines our inability to keep on the bleeding edge of advancement. Van Creveld states, “As of the opening years of the twenty-first century, the mightiest, richest, best-equipped, best-trained armed forces that have ever existed are in full decline and are, indeed, looking into an abyss.”

It is this precipice of disorder, which is brought about by our enemy’s use of asymmetrical warfare methods that drives the development of programs such as the Center for Network Innovation and Experimentation (CENETIX),

located at the Naval Postgraduate School in Monterey, CA. Since its inception, the program has been involved in the Field Experimentation Cooperative Program along with Department of Defense (DoD) entities, specifically United States Special Operations Command (USSOCOM), and numerous governmental research facilities that focus their expertise on areas that range from nuclear and biological agents to biometric identification. Simply put, the mission of the program is to enable operators on the front lines, whether they be a Boarding Officer at sea or a checkpoint guard in the Bavarian Alps, the ability to collect passive or active data on a target. They should then have the ability to expeditiously send it back to a designated subject matter expert who can provide pertinent feedback via the provided computer network connection. This seemingly simple concept could bring the knowledge of experts, such as those at Lawrence Livermore National Laboratories, right onto the deck of a dhow in the middle of the Arabian Gulf, possibly aiding in the identification of nuclear agents that previously would have been overlooked.

The experiments, which have taken place thus far, have pushed the boundaries of network operations and have exhibited the values we strive for when we talk about Network Centric Warfare (NCW). While the initial purpose of the experiments was to facilitate the above mentioned information exchange through the use of numerous network technologies, the current iteration of the program is something much bigger. It is for this reason that the opportunity is being taken to analyze past and present progress in order to identify, in an actionable way, what has and has not been deemed successful.

B. OBJECTIVES

The objectives of this study revolve around the ability of the various partnerships and technological combinations to provide the greatest benefit for all participating governmental, commercial, and educational entities. While there are numerous paths to success, the dynamic nature of the particular mission statements, which are held by each partner, mean that compromises may need to be made by some for the good of the entire group. This is not unlike the problems that consistently are faced by Department of Defense and Coalition Partners on a daily basis. A goal of this thesis is to determine at what point participation in the CENETIX experiments have historically proven to be more beneficial and to attempt to develop a model that would exploit those positive attributes in a timelier fashion.

C. RESEARCH QUESTIONS

1. Trends and Analysis

- What opportunities have exhibited themselves that deserve further experimental exploration?
- What successful experimental attributes can be extracted through analysis that may have not been previously noted and acted upon?

2. Capabilities

- Do current network capabilities serve the needs of experimental participants ranging from the Boarding Officer to the remote experts and observers?

- Would the addition of more commercial partnerships accelerate or inhibit capabilities?
- What capabilities have shown the most promise from networking, collaboration, and situational awareness perspectives?

3. Data Sharing

- Are the methods for data sharing made clear to all participants within the experiment? Are back-up collaboration avenues understood by all participants?
- Are the collaboration tools, which are currently used, robust enough for more complex and dispersed operational environments?
- Is there a single collaboration product or combination of products that could possibly serve the needs of all experimental partners?

D. SCOPE

The scope of this thesis is left intentionally broad in order to facilitate the on-going nature of the Field Experimentation Cooperative Program and to allow other researchers to perform further analysis in accordance with any number of research methodologies. Because the participation of such a varied group of partners is the hallmark of CENETIX research, a narrowing of the scope would lessen the degree that this analysis could be applied. To that end, this thesis will be used to analyze trends since the inception of the program through the experiment cycle designated as MIO 08-4.

E. METHODOLOGY

The methodology includes information gathered on the Global Information Grid (GIG), United States Special Operations Command (USSOCOM) capabilities, and extensive research of available literature, both hard copy and electronic, on wired and wireless computer network theories and practices. The author's intent was to develop ideas in accordance with a diverse group of professional and academic sources that directly pertain to 'feasibility and constraints analysis experiments' (TNT 08-2 OFDM 802.16 point paper). Additionally, the author focused on the extensive body of knowledge that has been collected in accordance with both the Tactical Network Topology (TNT) and Maritime Interdiction Operation (MIO) experiment cycles since 2005. These ever evolving experiments, led by Dr. Dave Netzer and Dr. Alex Bordetsky, primarily take place at Camp Roberts, CA and San Francisco, CA respectively.

F. ORGANIZATION OF THIS THESIS

The organization of this thesis is as follows:

Chapter I is consists of the introduction and the overview of this thesis. In this section, the author laid out the background, objectives, research questions, scope, and methodology.

Chapter II includes a comprehensive study into the myriad of collaborative tools, which have been used within the past few years, from the perspective of an NPS Network Operations Center (NOC) facilitator. Additionally, an analysis will be put forth that describes which suites have

been the most successful in filling the needs of the largest number of operators and subject matter experts (SME).

Chapter III will cover current, past and future sites and partnerships. In this chapter, the author will go more in depth into each of the sites that utilize the programs that are laid out within Chapter II. This chapter will also discuss the role of each specific site and to what extent each partnership has been successful at fulfilling the needs of each of the experimental partners.

Chapter IV shall include a comprehensive study into the myriad of collaborative theories and trends that have been explored by NPS researchers concerning the TNT/MIO experiments. The intent will be to attempt to discern a credible vision for CENETIX from the numerous bodies of work on the subject of collaboration and feedback mechanisms.

Chapter V will be used as the conclusion for this extensive retrospective look into collaboration within the CENETIX program. It is here that feedback is provided for improving the CENETIX partnership and strengthening the areas that may need more attention. This portion of the thesis will also be used to recommend future areas of study.

II. COLLABORATIVE TOOLS

A. CENETIX SITUATIONAL AWARENESS ENVIRONMENT

Developed in 2002 (Klopson and Burdian, 2005) by Eugene Bourakov, the CENETIX Situational Awareness (SA) tool has undergone extensive upgrades to facilitate the evolutionary nature of this experimental organization. Initially built to remotely control UAVs, the program has been adapted to track High Value Targets (HVT) as well as to monitor network backbone nodes. Additionally, the SA server command line interface can be utilized, via GPRS cell phones or IRIDIUM hand-sets, to transmit Point of Interest (POI) data to an Unmanned Aerial Sensor (UAS) in order to collect digital reconnaissance data (TNT 08-3 QLR).

In general, the highly modifiable SA environment, that employs readily available Flash MX technology, is indispensible within the TNT MIO experiments. This collaboration solution takes some of the best attributes from numerous programs and integrates them into a relatively lightweight suite, which can be utilized by any user that has access to the internet. Klopson and Burdian successfully completed an extensive study of the functionality of both the SA environment and server in 2005 which should be referred to for further information.

B. MICROSOFT GROOVE

As early as 2003, it was commonly understood by NPS researchers that the inclusion of a Commercial Off-the-Shelf (COTS) collaboration solution was going to play a

pivotal part in any feasible solution to the multi-organizational communication hurdle. Although the CENETIX SA environment has some impressive strengths, the ability to utilize an entire ‘virtual office suite’ could free up developmental resources to perform more pressing experimental duties, such as network management and trouble-shooting.

According to Microsoft (2008), Groove “is a collaboration software program that helps teams work together dynamically and effectively, even if team members work for different organizations, work remotely, or work offline.” The CENETIX partnership generally utilized the chat, discussion board, and file repository functions within the Groove suite. A benefit of the program is the ability to instant message individual participants within the experiment. It is also advantageous to have all of the members of the workspace listed along the left side of the window, as seen in Figure 1, to include their activity status (In workspace, Online, & Offline).

The functionality of Groove has periodically been hampered by an unexpected learning curve during recent experiments. This learning curve revolves around the installation of the program on remote computers and the specific manner in which the CENETIX team uses the workspaces. Installation problems come about because of the registration keys and invitations used to both install the program and to join specific CENETIX workgroups. Because of the server-client structure of this program it would be more beneficial if the installation was more intuitive and if the keys distribution could be more automated.

Currently a new user must request a new installation key from Mike Clement, and then they must be invited to each individual workspace.

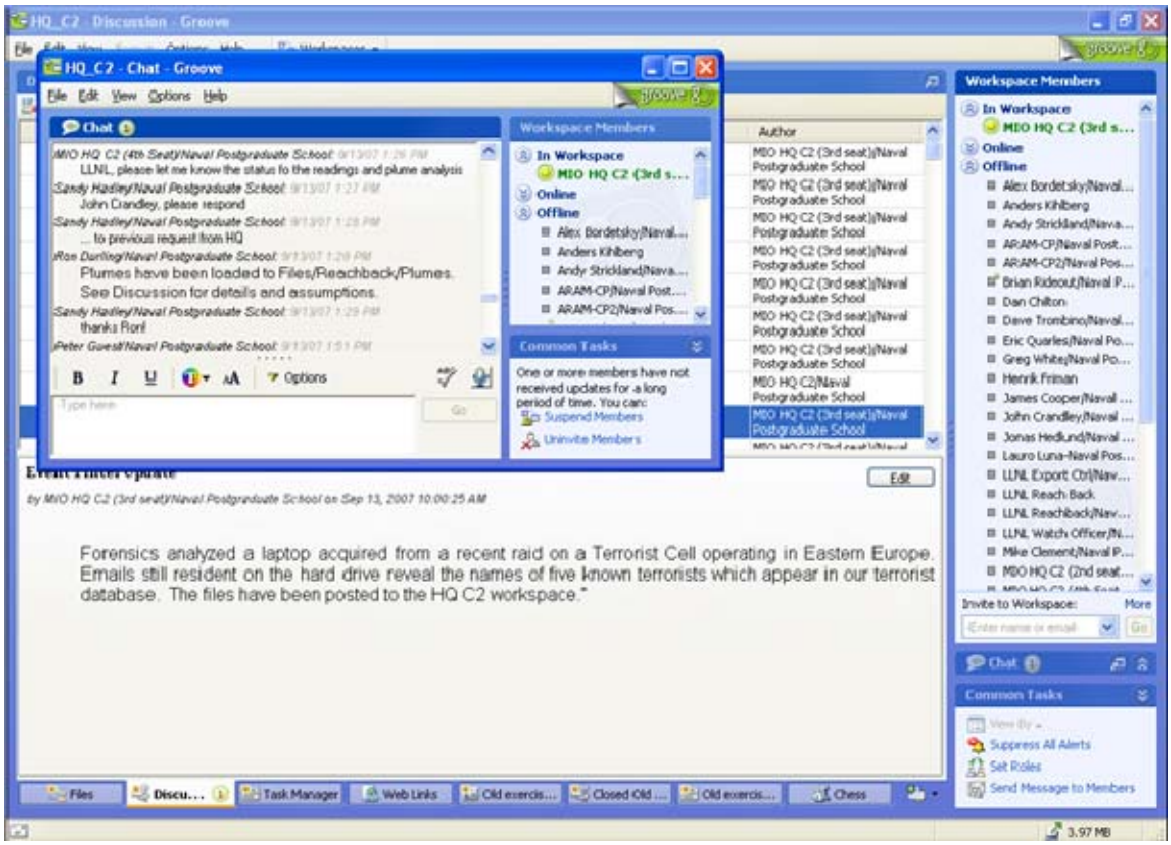

Figure 1. Groove Workspace

Mr. Clement has alleviated many of the 'growing pains' that were first felt while using this program by proactively testing and troubleshooting installations and workspace functionality prior to the beginning of each experiment cycle, most notably 08-3 and 08-4.

This heightened level of attention to the problems with Groove came about in direct response to lessons learned during TNT 08-2. According to the 08-2 AAR, "Users signed on at Aarhus Harbour site (TOC, vessel) were not

able to see each other online," files larger than 10Mb would halt all message synchronization, and multiple workspaces caused general confusion within the remote sites. The first two problems could be attributed to server-client nature of the program, while the workspace confusion was alleviated by on-site training by NPS personnel. In general, these problems were lessened to a great extent by 08-4 because of the relative familiarization by all of the experimental partners. To continue this positive trend, it is suggested that each experiment begin with a run-down by administrators of alternative methods of communication, such as the Observer's Notepad and VC1, in case Groove goes down.

C. PANYNJ JOINT SITUATIONAL AWARESNESS SYSTEM (JSAS)

The solution chosen by the Port Authority of New York & New Jersey (PANYNJ) to address the problem of cross-agency communications is the Joint Situational Awareness System. When testifying before the U.S. Senate Committee on Commerce, Science, and Technology, Anthony Coscia, the Chairman of PANYNJ stated that "JSAS is a DHS-funded, DoD managed and Port Authority-led multi-agency project to build an information sharing and collaboration network among key operations centers in the New York and New Jersey port region. Regional partners include the States of New York and New Jersey and the City of New York. DHS sponsorship is via the Domestic Nuclear Detection Office (DNDO)." This extremely compact suite of applications is tasked with the mission of providing "shared situational awareness and a common operational picture of security events and other emergencies" (JSAS Overview, 2007) to a

consortium of local emergency responders. The organizations presently included are the PANYNJ, the New York State office of Homeland Security (NYS OHS), the Metropolitan Transportation Authority (MTA), the New Jersey Office of Homeland Security and Preparedness (NJ OHSP), and the New York City Office of Emergency Management (NYC OEM) to include other New York City governmental agencies. The physical orientation of these organizations can be seen in Figure 2.

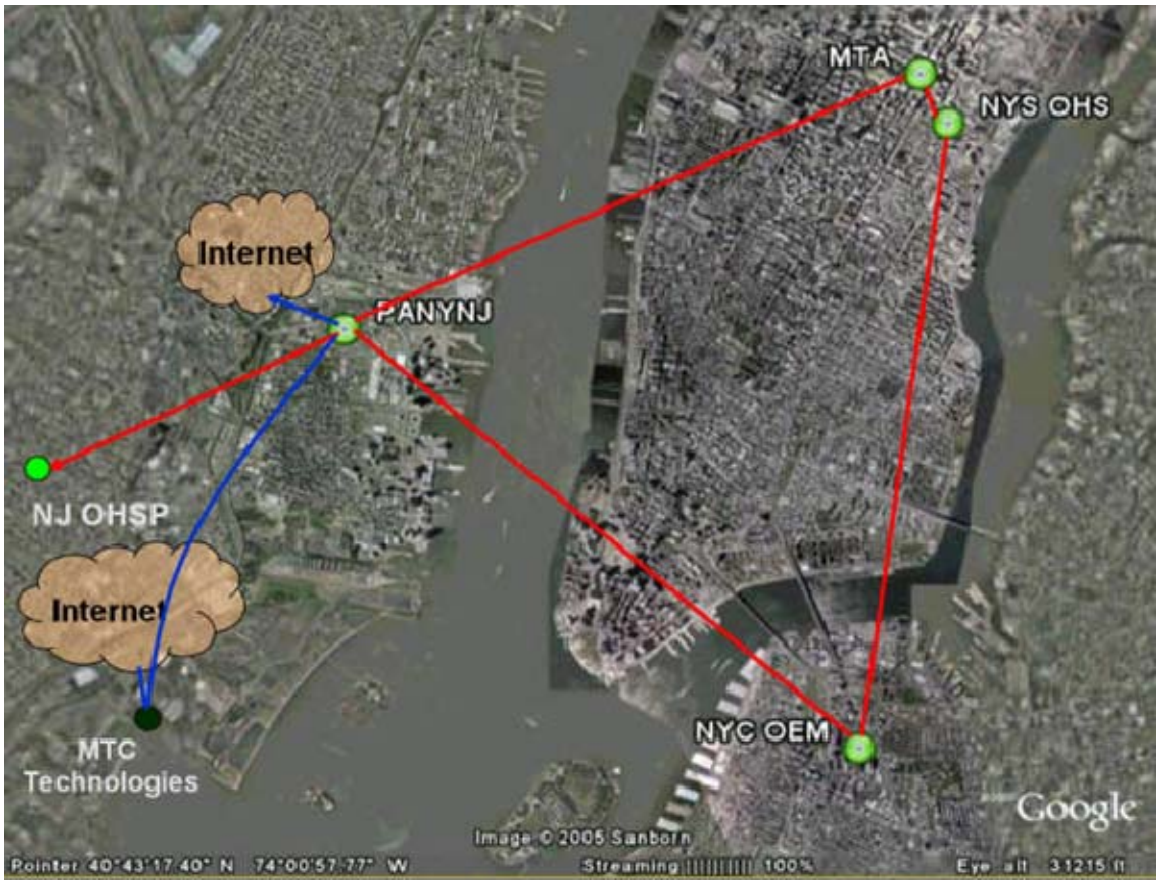

Figure 2. JSAS Geographic Distribution
(From JSAS White Paper, 2007)

The JSAS is a comprehensive solution that was built on the premise that 80 percent of the information and functionality provided by the portal should be understandable by any user within a three minute training session. This ambitious requirement is made more important by the fact that the system was developed to be used by decision makers during natural or man-made disasters, rather than on a daily basis. All indications during the TNT MIO 08-4 experiments are that the team has been extremely successful at attaining this measure of operability.

During the TNT MIO 08-4 experiments, which began on September 8, 2008, the JSAS was utilized by all participants as the main avenue for communicating the status of the MIO scenario, to include alerts and weather data. The main portions of the suite that were taken advantage of were the JSA Portal, which provides real-time threat advisory alerts, and the JSA Executive Viewer, shown in Figure 3, which “brings together the various information sources including video, alert, map, and contact information” (JSAS Overview, 2007).

Figure 3. JSAS Executive Viewer
(From JSAS White Paper, 2007)

In addition to the Portal and the Executive Viewer, the JSAS provides a comprehensive Collaboration Services (Figure 4) system that can provide voice, video, and text collaboration through a PC, a phone of video teleconferencing system (VTC), and the JSA Network Monitoring System, which encourages sustainability of the project by collecting and authenticating the status and content of the various network enabled sensors.

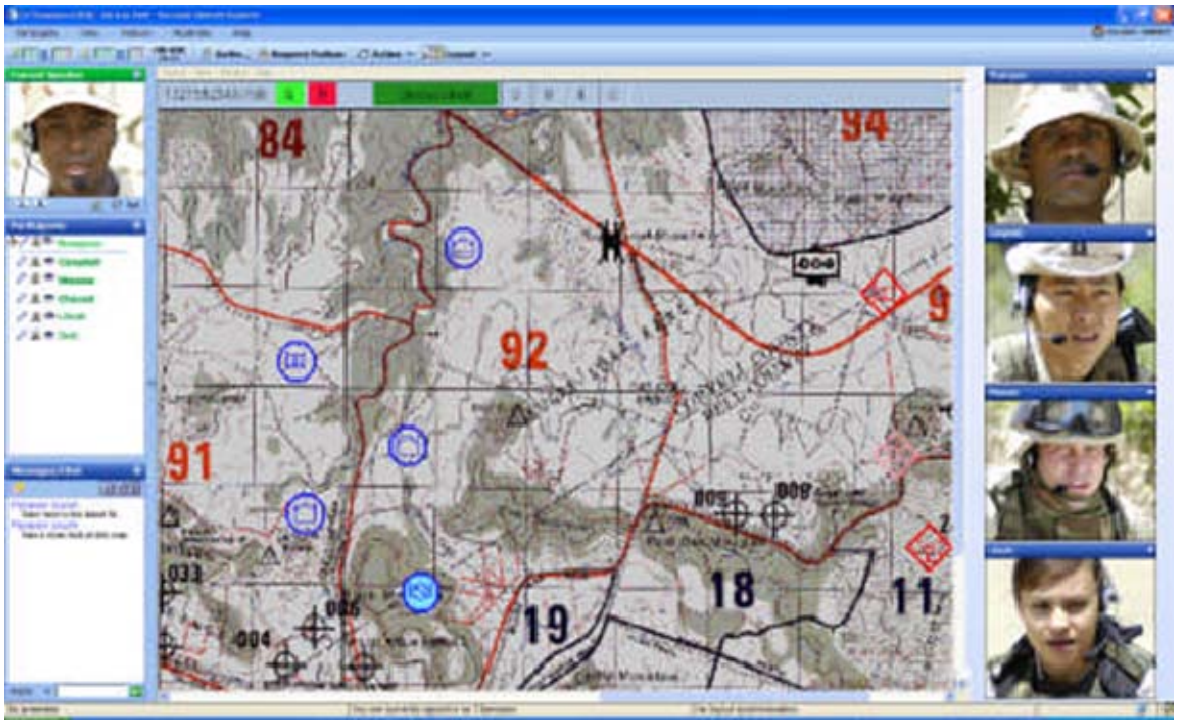

Figure 4. JSAS Collaborative Service
(From JSAS White Paper, 2007)

As a whole, the PANYNJ JSAS solution is an extremely encouraging step in the right direction for multi-agency collaboration and knowledge sharing, although it does have room for improvement in the realm of ad hoc communications between individual experimenters. During the 08-4 experiment cycle, NPS personnel did maintain their standard suite of collaborative avenues (SA, Google Earth, and Observer's Notepad) in conjunction with JSAS in order to facilitate continuity with the partners who were not familiar with JSAS.

Possibly the most remarkable portion of the suite is the ability to bring together video and sensor data from all over the New York City area, including ad hoc feeds from outside organizations like CENETIX, into a

comprehensible format is very impressive. Additionally, the ability of the suite enable decision makers the option to communicate via numerous avenues while experts on the ground are able to inject minute-by-minute updates, via alerts, is imperative to the mission they are trying to accomplish. The purposeful ease of use and simplicity only adds to the allure of this collaborative option although it still falls short as an all encompassing solution.

D. CENETIX OBSERVER'S NOTEPAD

The ability to accurately analyze what has happened during an experiment is paramount. When one considers the work load that each participant is tasked with during the typical scenario it is understood that information gathering is necessary, yet difficult. While the Observer's Notepad is not acknowledged as a true collaborative tool, it does an exceptional job at enabling retrospective analysis of the information gathered, especially from the network management perspective. Entries by participants are time stamped and organized into chapters based on the specific experimental cycle.

Recent changes, shown in Figure 5, by Eugene Bourakov to include screen names and the ability to upload pictures are welcome improvements that will only further the notepads usability. It should also be noted that the notepad is also utilized by NOC personnel when other collaborative technologies appear to go down.

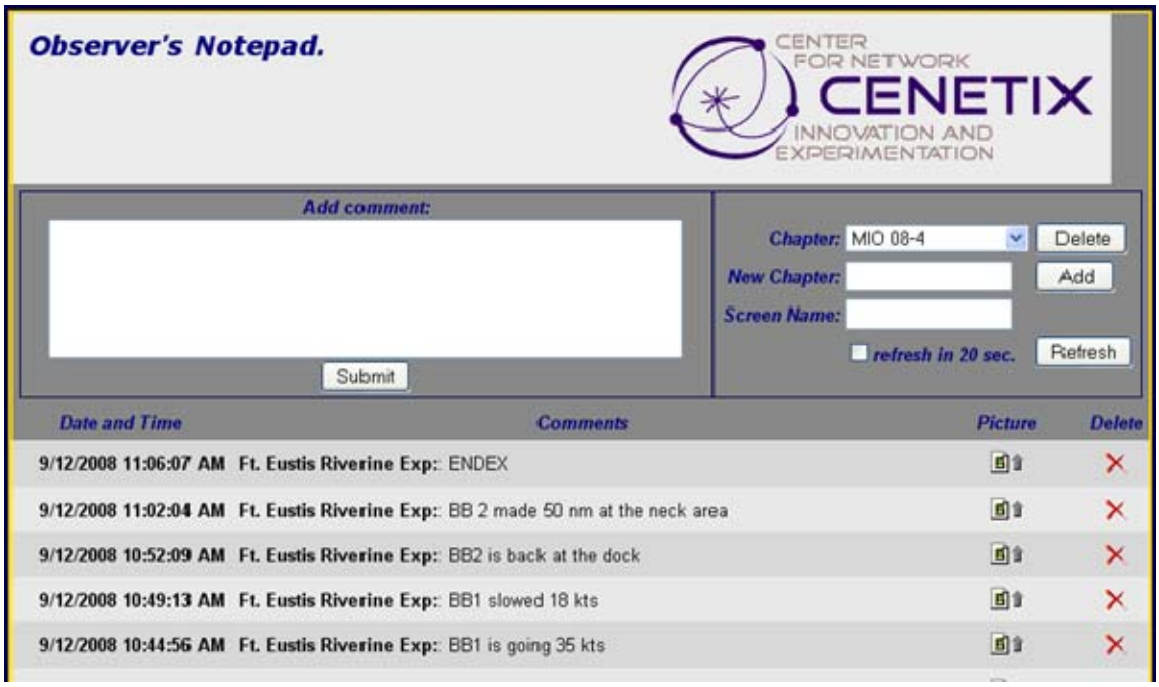

Figure 5. Observer's Notepad

E. CENETIX VIDEO CONFERENCE ROOMS

The sheer range of CBR agents that a boarding team could be faced with, in addition to traditional weapons and the possibilities of both drug and/or human trafficking, make it impossible to have all of the expertise needed within a single team. It is for this reason that real-time video transmissions have been at the forefront of the desired capabilities list for the CENETIX partners. Although this has subsequently been accomplished through many systems, such as Groove and JSAS, the CENETIX video conference rooms, commonly referred to as VC1, VC2, and VR3, are at the core of the partnerships capabilities.

Through the use of these web-based portals Boarding Officers (BO) have been able to successfully stream video to and from the Tactical Operations Center (TOC) while

going aboard suspect vessels and performing their assigned searches and seizures. This capability is extended by the ability to chat, send data files, and communicate via voice to anyone within the portal. During the experiments between December 2006 and September 2008, the only notable problem, experienced within this approach to communicating with the boarding party, from a collaborative standpoint, is the inability to pull all partners into the same room if another one becomes inoperable due to hardware or network issues. This problem was mitigated to some extent by providing hands-on training at partner sites by NPS students. One notable upgrade, brought about by the addition of Video Room 3 (Figure. 6), is the ability record or upload and store data feeds in a browser-embedded Flash player for review after the completion of the experiment. This capability will no doubt be extremely beneficial as the After Action Reports (AAR) are composed.

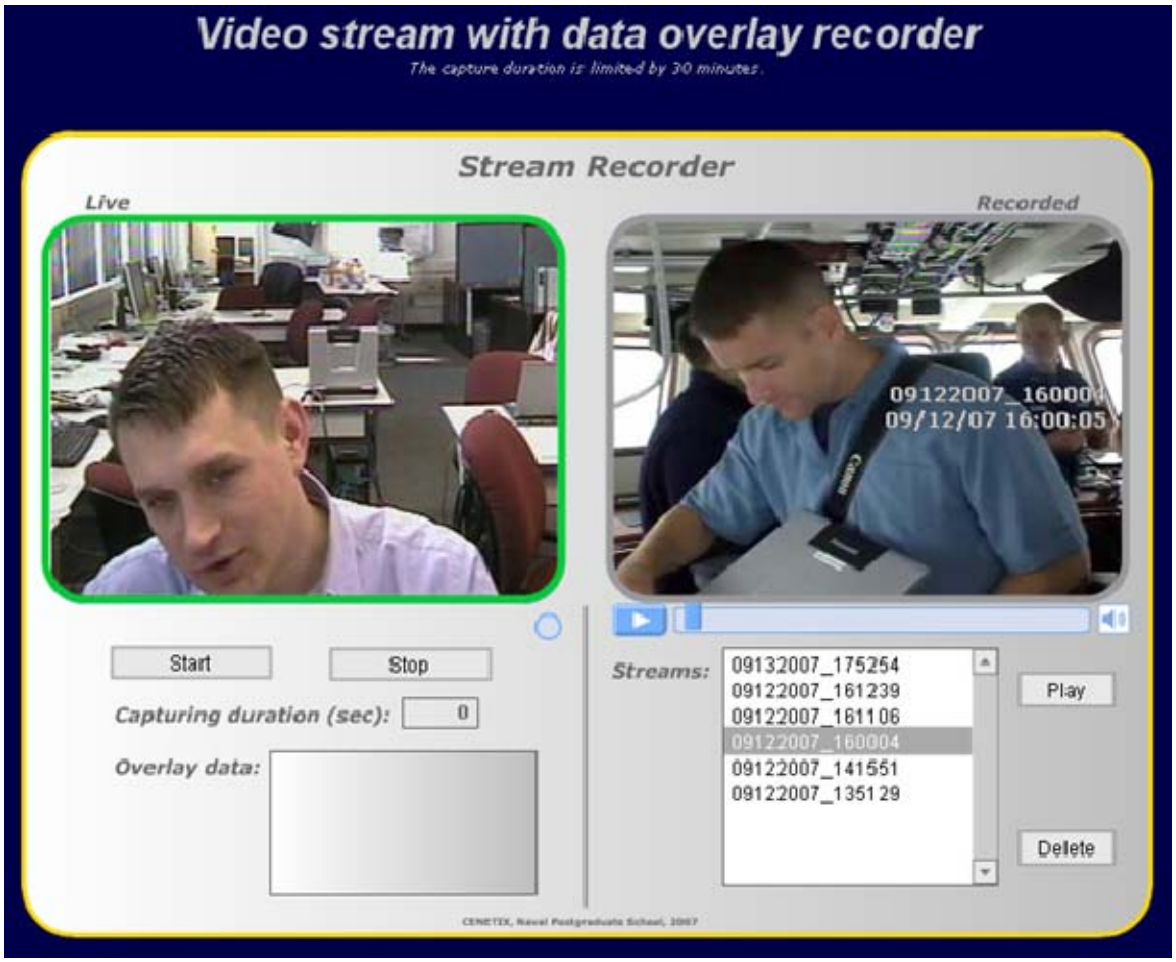

Figure 6. VR3 Video – Live TOC/Recorded BO.

F. CENETIX IP BASED VIDEO FEEDS

In addition to browser based portals, the CENETIX Lab also utilizes a wide range of IP based cameras, most notably from Pelco, to capture and share data across the network. These cameras are each assigned a static IP address within the 192.168.99.xxx sub-domain and they can be accessed using the Pelco internet browser plug-in. Through this proprietary plug-in some cameras can be controlled from the pan/tilt and zoom perspectives. This method of access has also been used to provide video

feedback from numerous autonomous platforms to include unmanned aerial vehicles and unmanned surface vehicles. Figure 7 is an exceptional example of an aerial pursuit and observation from two UAVs and a static camera placed on the communication tower at Camp Roberts. This feed was captured, without any noticeable lag or interference, at the Network Operations Center, located nearly 100 miles away in Monterey via the 802.16 OFDM wireless backbone.

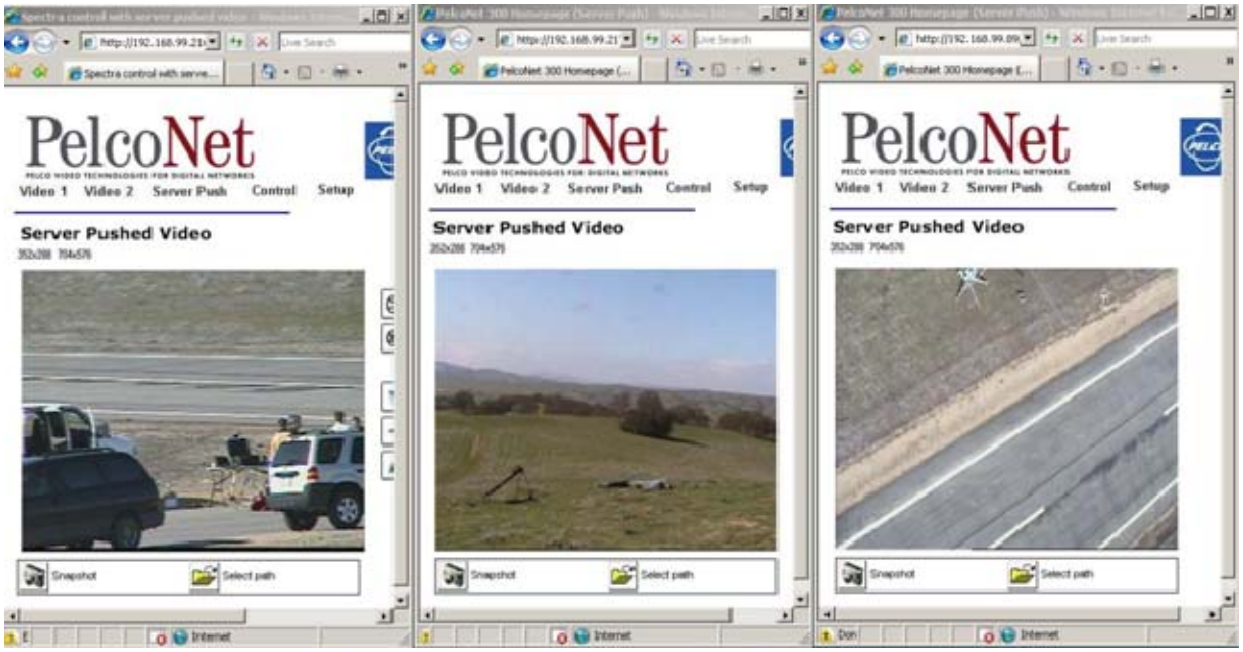

Figure 7. Simultaneous Video via 802.16 OFDM Backbone

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III. MAJOR COLLABORATIVE SITES AND ROLES

A. MILITARY PARTNERSHIPS

1. United States Special Operations Command

"The United States Special Operations Command" (USSOCOM or SOCOM) is the Unified Combatant Command charged with overseeing the various Special Operations Commands (SOC or SOCOM) of the Army, Air Force, Navy and Marine Corps" (Wikipedia, 2008). As the primary sponsor for the TNT/MIO experiments, USSOCOM directly contributes to the relevancy of the scenarios that are performed at Camp Roberts and in the San Francisco Bay area. These scenarios are intended to hit right at the heart of the practical mission laid out by Admiral Eric T. Olson, Commander USSOCOM, when he spoke to the Naval Postgraduate School student body. The Admiral stated that "Technology is only good when it is useful. Shape your product for the warfighter. Do not ask them to subscribe to your hobby." He went on to say that our forces "do not need more shiny objects."(NPS SGL, 2008)

The no-nonsense charge by Admiral Olson does not fall on deaf ears. Mr. James Cluck, Director of Special Operation Networks and Computers (SONC), identified the need to "foster inter-agency cooperation" and the need to "obtain persistent Intelligence, Surveillance, & Reconnaissance (ISR)" systems as command priorities within USSOCOM. Subsequently, the intent of the USSOCOM-NPS cooperative is to provide exactly the relevant networking and collaborative technologies that the warfighter can put into use with minimal experience and maximum reliability.

The specific objective is “to provide an independent assessment capability to evaluate effectiveness, affordability, and feasibility of future capabilities, and to provide a unique education and research environment for students and faculty at NPS. Secondary objectives include examining dual-use capabilities for homeland security, stabilization, reconstruction, and disaster relief/humanitarian assistance, and for other government agencies” (08-3 QLR, 2008). This unique mixture of NPS faculty and military student researchers, in conjunction with SOCOM operatives, is paramount in achieving a true network-centric warfare (NCW) model. Perry et al. (2002), define NCW as “the linking of platforms into one, shared awareness network in order to obtain information superiority, get inside the opponents decision cycle, and end conflict quickly.” The extraordinary relationship between military students and boots on the ground operatives greatly enhances the ability of the cooperative to meet this DoD wide goal.

2. United States Coast Guard

If there is one organization that could fully benefit from the MIO research performed within the CENETIX experimental scenarios, it is the U.S. Coast Guard. The role of the USCG within the Department of Homeland Security is driven by a responsibility to monitor our coastal waterways, to include riverine areas to ensure that neither dangerous persons nor materials breech our borders. Just as the Clinger-Cohen Act eventually revolutionized the mindset within the Department of Defense, the Maritime Security Act of 2002 and the Security and Accountability For Every Port

(SAFE) Act of 2006 (SAFE) will both play a large part in modernizing the Command and Control (C^2) systems within the USCG. Both of these Acts have specific stipulations that require a much more vigorous look at information sharing, collaboration, and contingency planning through a layered defense architecture. This push toward information fusion or Maritime Domain Awareness (MDA) was also reiterated by the President in his National Strategy for Maritime Security. In fact, that strategy defines MDA as "an effective understanding of anything in the maritime environment that can affect the safety, security, economy, or environment of the United States" (Coscia, 2008). From this viewpoint the participation within the MIO experiments by the USCG is much more than just a simple exercise in logistics, they are stakeholders with a vested interest in the success of the research that is performed.

B. GOVERNEMENTAL PARTNERSHIPS

1. Lawrence Livermore National Laboratories

The long standing participation of LLNL within the TNT-MIO experiments is advantageous on a multitude of levels, as explained by Dr. Alex Bordetsky. "The operational focus of NPS-LLNL experiments is on finding viable solutions for MIO connectivity and collaboration providing for rapid radiation detection, biometrics identification, non-proliferation machinery parts search, and explosive materials detection on board the target vessel during the boarding party search phase. The Testbed includes mesh and long-haul wireless networking with radiation detection sensors, boarding party collaboration with remote expert teams, and reachback to different

locations around the globe” (Bordetsky, et al. 2006). To simplify, LLNL not only provides remote expert intelligence in regards to radioactive materials, but they also provide critical communication solutions to include Ultra-Wideband radios (UWB).

Most notable among LLNL’s collaborative contributions is their ability to remotely identify radioactive material based on signature data which is gathered by any number of provided sensors. The sensors to include externally mounted drive-by models, handheld units such as the IdentiFINDER, and the Adaptable Radiation Area Monitor (ARAM), illustrated in Figure 8. While the handheld IdentiFINDER, shown in Figure 9, is meant to be used by Boarding Party (BP) members involved in Maritime Interdiction Operations (MIO), the ARAM system was developed to be “a portable system that can detect small amounts of radioactive materials from a distance. When radioactive material is detected, ARAM photographs the area, collects high-resolution spectral data for analysis, and rapidly sends the information to a first responder” (Vergino, 2004).

Figure 8. LLNL Adaptable Radiation Area Monitor
(From Vergino, 2004)

This sending of data to the first responder and then on to LLNL, via the TNT backbone, is the key to the collaboration that takes place between the BO and the remote knowledge expert who can instruct the BO on exactly what type of materials they are dealing with. Whether it be the legitimate components of a “dirty bomb” destined for our shores, or a container of smoke detectors, which each contain 0.9 micro curie of Americum-241 (McQuay, 2008), the first responder can rest assured that he will quickly be greeted by a positive or negative signature identification from the staff at LLNL, via the TNT Testbed.

Figure 9. Thermo Scientific Isotope identiFINDER (From Thermo Scientific, 2008)

In conclusion, both sensors are part of a study to detect nuclear weapons of mass destruction and radiological "dirty bombs" in remote locations which help CENETIX meet the problem that was illuminated by General Mattis, USMC, during a recent visit to the Naval Postgraduate School. In his current position as the Supreme Allied Commander of Transformation and the Commander of U.S. Joint Forces Command, he has a unique picture of our military capabilities and priorities. He stated that "One of the two main technological areas we must address is our ability to identify Weapons of Mass Destruction coming into our

airports and seaports” (NPS SGL, 2008). Luckily that is precisely the mission that LLNL has taken on, with the help of CENETIX, within the TNT-MIO experiments.

2. Biometrics Fusion Center

Established in 2000 in Clarksburg, West Virginia, the Department of the Army Biometrics Task Force Biometrics Fusion Center is utilized as a remote expert site during the CENETIX experiments.

> The BFC performs test and evaluation of Commercial Off-the-Shelf (COTS) biometrics, supports the development of standards and performance measures, provides biometric repository support as required, and provides technical implementation and integration support to Department of Defense (DoD) Biometrics. Among its core functions are synchronizing and integrating existing and new technologies throughout DoD; providing identity dominance, protection, and management through integrated joint biometric programs; and establishing and maintaining an authoritative biometric data source in order to provide timely, accurate and comprehensive Identity Superiority to the warfighter. (WV Biometrics Initiative Website, 2008)

Just as LLNL provides expert radiological advice remotely, the BFC is responsible for assisting boarding parties or check point personnel with up to the minute data pertaining to suspected persons of interest. Obviously this must be performed through the use of an extremely robust database in conjunction with some method of network communication between the field operator and the BFC. At the present time, this is performed by using a dedicated VPN connection between the TNT-MIO Testbed and the BFC as shown in Figure 10, while the more generalized view from

sensor to VPN can be seen in Figure ll. Because of the possible hostile nature of Maritime Interdiction, the ultimate goal of CENETIX has been to decrease the time between data acquisition and the response from the Fusion Center, while concurrently increasing the reliability of the network connection between the two. Just as with any experiment, this desire to improve communication has called for a certain amount of ingenuity.

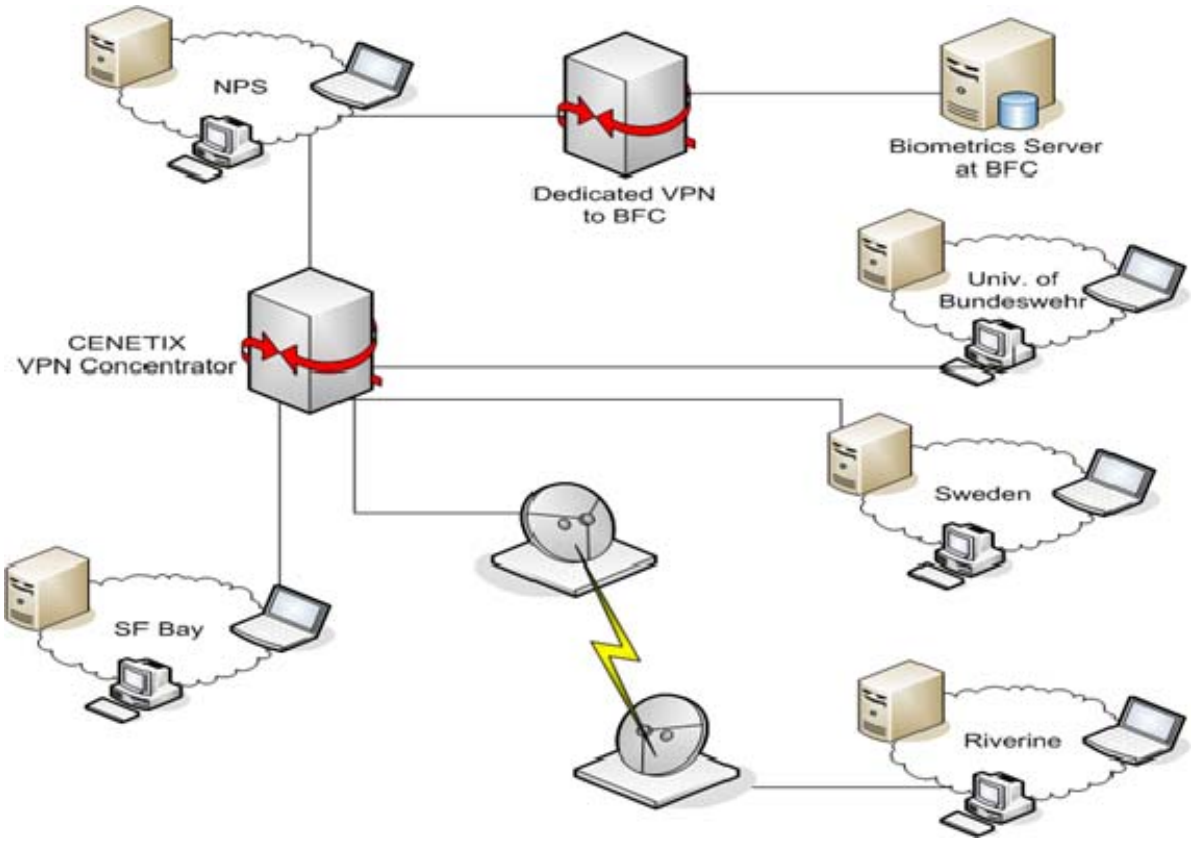

Figure 10. Network Topology Reach Back to BFC
(From 08-2 After Action Report, 2008)

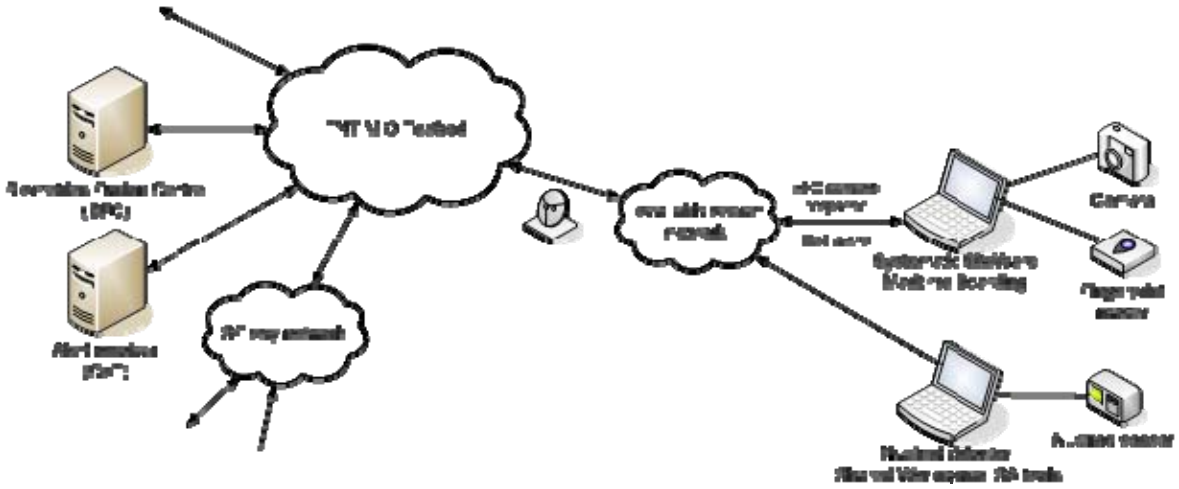

Figure 11. Biometrics Sensor Reach Back to BFC
(From 08-2 After Action Report, 2008)

For example, during the Aarhus, Denmark MIO portion of 08-2, the biometrics data that was collected on the target vessel (see Figure 12) was not able to pass directly back to the BFC via the provided global network because of a problem with FTP permissions (NIPRNET). In this specific case, Groove was also not performing as expected, so it was not an option for signature transmission. The decision was made to manually intervene and exchange files via e-mail, which enabled a positive identification of the person of interest. Although this was not the preferred method for information exchange, it did provide a positive match, which is considered a success from a collaboration stand point. In the future, a positive FTP access test should be performed in order to alleviate this type of trivial problem when attempting to reach back to the BFC.

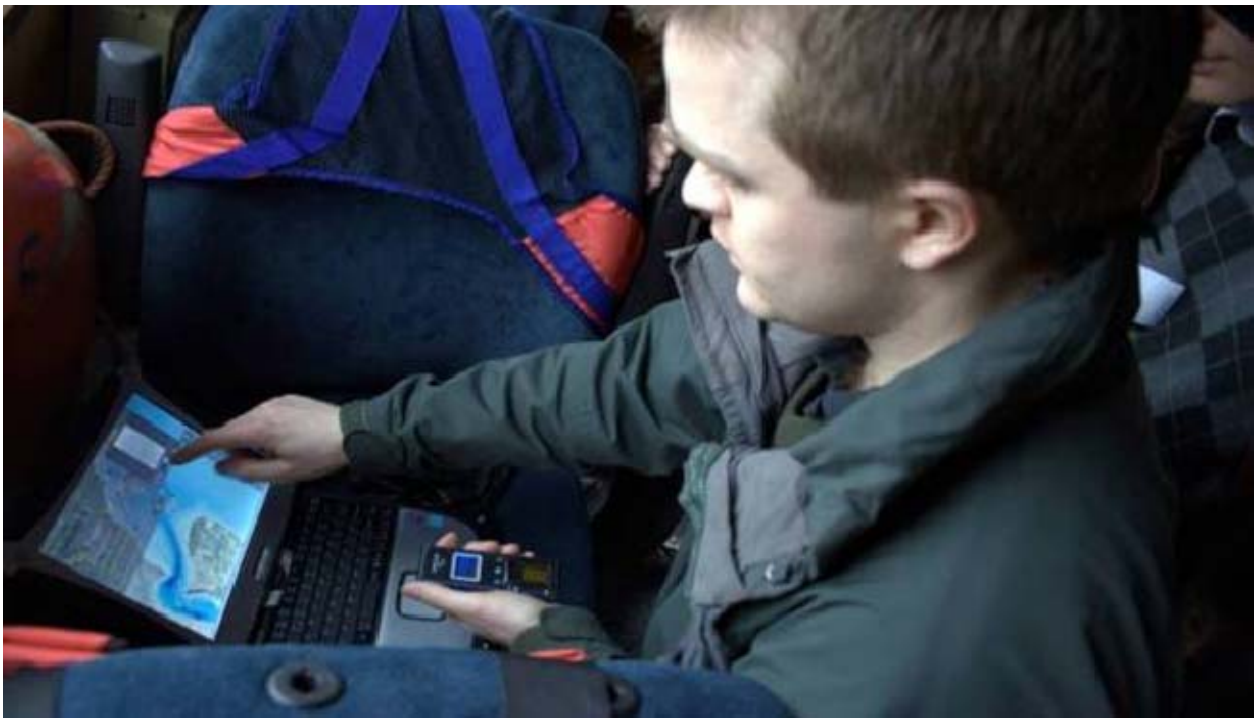

Figure 12. Crew biometrics gathering in Aarhus
(From 08-2 After Action Report, 2008)

C. CONTRIBUTING FOREIGN AND DOMESTIC PARTNERS

1. Port Authority – New York / New Jersey

The Port Authority of New York and New Jersey, established in 1921, is a bi-state organization responsible for an area of about 1,500 square miles centered on the Statue of Liberty, as shown in Figure 13 (PANYNJ website, 2008). PANYNJ is also responsible for a majority of the regional transformational infrastructure, including tunnels, bridges, airport, and seaports within the New York-New Jersey Port district (Wikipedia, 2008). While the Port Authority does manage the Port Newark-Elizabeth Marine Terminal, which is the largest on the Eastern Seaboard, their ownership of the World Trade Center has been cause for the largest changes within the organization. During the

fatal terrorist attacks on the World Trade Center on September 11, 2001, the organization's headquarters, which was located in Tower 1, was destroyed, taking with it the lives of 84 employees, 37 of whom were police officers or commanders(PANYNJ Annual Report, 2002).

Figure 13. PANYNJ Area of Responsibility
(From PANYNJ.gov, 2008)

This tragedy brought about a sea change within the organization that revolved around a much broader command

and control structure, which could more readily react to attacks or incidents within their region. This is achieved through the formation of geographically dispersed Emergency Response Centers, as seen in Figures 14 & 15, and through the use of satellite enabled Emergency Response Vehicles (Figure 16). This is precisely where the concepts that have been explored through the CENETIX TNT Testbed come in, since the concept of distributed C^2 has been extensively studied through the use of the Tactical Operations Center (TOC) and Network Operations Center (NOC) paradigms. In addition to the TOC and NOC, the interjection of feedback by a multitude of domestic and international partners to the scenario-driven MIO experiments promises to provide PANYNJ with answers to the problems which they have been trying to solve since that fateful day in 2001.

Figure 14. PANYNJ Emergency Response Center

Figure 15. PANYNJ Emergency Response Center Alternate

Figure 16. PANYNJ Emergency Response Vehicle

It is well known that the Port Authority has decades of experience in law enforcement, bridge/tunnel construction and protection, and port security that can be of great value to the other CENETIX partners. Although the level of diversity within the organization is difficult to grasp, it is not unlike the broad range of responsibilities shared by the U.S. Coast Guard. In fact, the inclusion of both of these entities will hopefully lead to partnerships, which will ease the burden felt by both organizations in the realm of radiation detection, information sharing, and force protection. The participation of the PANYNJ has been a welcome addition to the experiments since TNT-MIO 07-3 (Mercado, 2008). During the MIO 08-4 experiment cycle, the NPS team transitioned from the West Coast to the East Coast in order to demonstrate their capabilities in and around the Newark region. During this on-site experiment, PANYNJ brought in numerous new partners, which are shown in Table 1.

NYC Area MIO Participants
United States Coast Guard
Customs Border Protection
Port Newark-Port Authority of NY & NJ
PAPD EXPERIMENT Police
PAPD Emergency Services Unit
Port Authority Office of Emergency Management
Jersey City/Newark/ Elizabeth Fire Departments
New York Police Department
Fire Department NY
NYC Office of Emergency Management
New Jersey State Police Maritime Division
Stevens Institute

Table 1. PANYNJ MIO Experiment Partners.

(After TNT-MIO 08-4 Scenario, 2008)

2. San Francisco Bay Area Law Enforcement

During the MIO portion of the CENETIX experiments, assets are provided in the form of transportation, relay access, and manpower from the Alameda County Sherriff's Marine Unit (06-4), the San Francisco Police Marine Unit (06-3), the Golden Gate National Recreation Area U.S. Park Police (07-1), and the Oakland Police Special Operations Unit (06-4). The numbers within parenthesis following the unit name represents the first TNT-MIO experiment cycle which they participated in. Each of these organizations provides intelligence reports and interdiction tactics to further assist the C^2 elements in finding maritime terrorists or High Value Targets (HVT) (Mercado, 2008).

The network, which is demonstrated during the Maritime Interdiction Operations, performed within the San Francisco Bay area most closely represents the layout which is illustrated in Figure 17. As can be seen, the topology is used to demonstrate the abilities of numerous technologies to include Self-Aligning OFDM 802.16 (SAOFDM), which is used for ship-to-ship and ship-to-shore communications; Ultra-Wideband, which is used for through-the-deck communications; Wave Relay and ITT mesh relay, which are sued to connect numerous sensors and vessels; and TACHYON satellite nodes, which are primarily used for reachback from remote riverine areas. The majority of these communication platforms could be easily mounted and exhibited from any number of Bay Area Law Enforcement assets in order to provide extended C^2 capabilities.

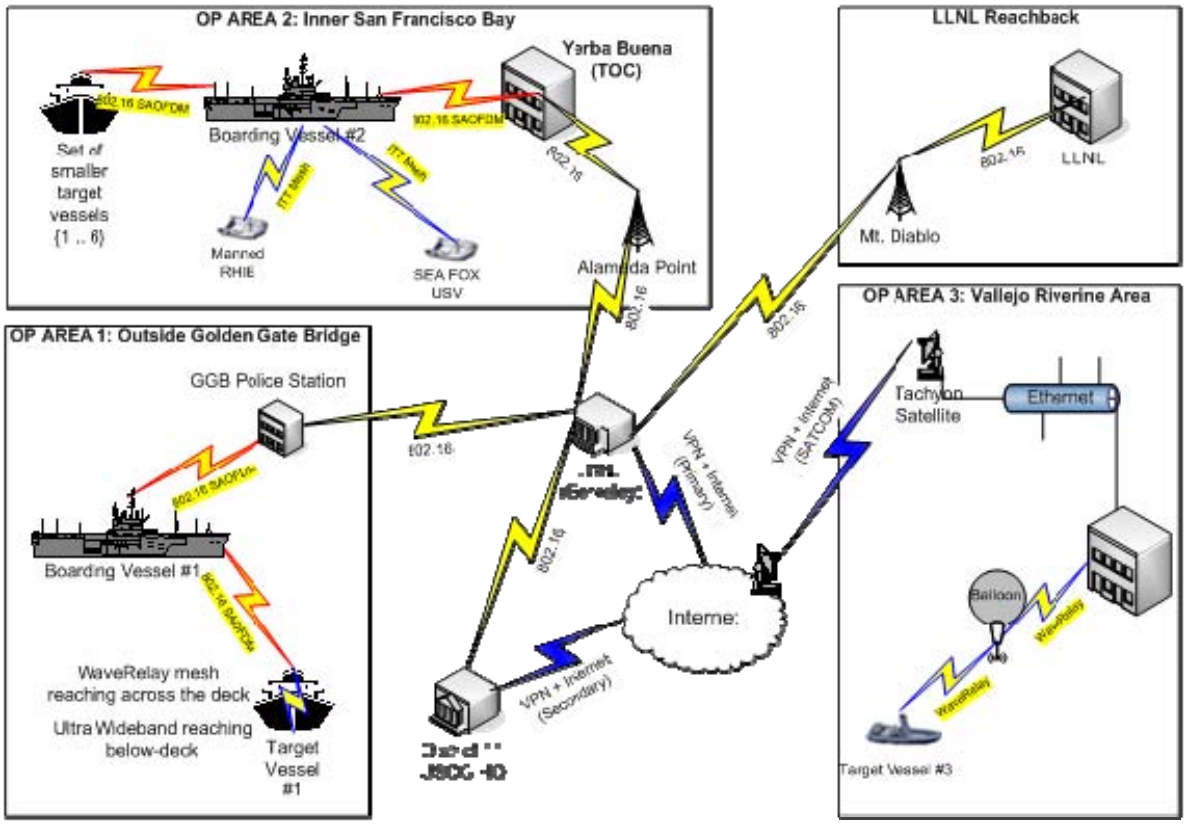

Figure 17. San Francisco Bay Area Network Topology (From TNT-MIO 08-2 AAR, 2008)

3. Coalition Partners

The inclusion of geographically disbursed foreign and coalition partners, as seen in Figure 18, has brought about a broader perspective than was seen when the experiments were of an entirely domestic nature. Since 2005, the following partners have been added, with the corresponding TNT-MIO cycle noted in parentheses: Swedish Naval Warfare Center (06-3), National University of Singapore (06-4), Salzburg Research (07-3), University of Bundeswehr (UoB) at Munich (07-3), the Danish Navy Training Center (08-2), and the Turkish Air Force Academy (08-2) (Mercado, 2008). Because the concept of Joint warfare is at the epicenter of

current military dogma, the addition of the coalition partners adds to the real world scenario driven environment which is being fostered within the CENETIX experiments.

Figure 18. Domestic and Coalition Sites
(After Michael Clement, 2008)

The progression from remote observers and collaborators to primary experiment participants by the European partners, which are geographically distributed as shown in Figure 19, took place during the MIO 08-2 experimental cycle. The institutions, which increased their roles dramatically by hosting the NPS team, included the Swedish Naval Warfare Center (SNWC) in Karlskrona, Salzburg Research near the German-Austrian border, the University of Bundeswehr (UoB) in Munich, Germany, and the Danish Navy Training Center located in Aarhus, Denmark. The relatively close proximity of each partner lent itself very well to the scenario, which is described below.

Figure 19. European Partner Locations

The specific contributions during MIO 08-2 revolved around a scenario in which a suspected radiological/nuclear source was detected within a vehicle at a checkpoint along the German border. Following identification of the source by remote experts at LLNL, the occupants were scanned biometrically and the car was tagged, released, and monitored as it traveled across Germany, through the Port at Gdynia, and into Sweden. The specific route, which was successfully monitored by all remote participants is shown in Figure 20, via a time lapsed screen capture of the Google Earth enabled SA environment. The individual

collaborative contributions of the European partners with the tagging and tracking of the experimental High Value Target (HVT) are listed below.

Figure 20. HVT remotely tracked across Europe (From MIO 08-2 AAR, 2008)

a. UoB in Munich, Germany

The University of Bundeswehr has played an extensive role within the MIO experimentation by providing a great deal of experience with the checkpoint operations. (A. Bordetsky, personal interview, October 29, 2008) This includes the use of the LLNL ARAM sensor (Figure 21) to identify HVT vehicle, the act of physically locating the radiological/nuclear item within the vehicle (Figures 22 & 23), the biometric scans of the occupants (Figures 24 & 25), and the tagging of the suspect vehicle for tracking

via a prototype GPS tagging device (Figure 25). It should be noted that positive rad/nuc agent identification took place within three minutes between the checkpoint team and the remote experts at LLNL (MIO 08-2 AAR, 2008).

Figure 21. Vehicle configured with LLNL ARAM sensor (From MIO 08-2 AAR, 2008)

Figure 22. The nuclear radiation source is discovered (From MIO 08-2 AAR, 2008)

Figure 23. Camera Lens used to set off ARAM Sensor
(From MIO 08-2 AAR, 2008)

Figure 24. Biometric data is gathered from suspects
(From MIO 08-2 AAR, 2008)

Figure 25. Biometrics scanner and tag components
(From MIO 08-2 AAR, 2008)

Figure 26. Prototype Location Tag inside HVT vehicle
(From MIO 08-2 AAR, 2008)

b. SNWC in Karlskrona, Sweden

While the participation of the Swedish Naval Warfare Center in Karlskrona during 08-2 was the first time they had hosted the NPS team during the experiments, they had been instrumental with certain technologies for some time. When interviewed, Dr. Alex Bordetsky identified the ability of SNWC to provide specialized MIO drive-by detection and sensor enabled vest technologies as their strongest contributions to the experiments. (A. Bordetsky, personal interview, October 29, 2008). In fact, during MIO 08-2 the specified "goal for the Swedish team was to find the vehicle on board the ferry and take it for further biometric and nuclear radiation detection, including the use of a sensor vest and the Kockums unmanned surface vehicle" (MIO AAR 08-2).

The Piraya tactical unmanned surface vehicle (TUSV) that is employed by the Swedish team is an extremely modifiable prototype platform that measures in at 4m x 1.4m (Figure 27). The interchangeable payload consists of UHF, WLAN, 3G/UMTS/HDSPA, and satellite communication suites, LLNL provided rad/nuc sensors, and video capabilities. (Kockums Piraya TUSV Brief, 2008). Positional data was transmitted back to the Karlskrona TOC (Figure 28) via a 1 Hz UHF channel, which was fed into the Distributed Blue Force Tracker Software (DBFT) suite. "Selected objects such as the positions of the Pirayas and selected AIS data sets (i.e., a suspect merchant vessel) were extracted, converted into Cursor-on-Target (CoT) data and submitted to the TNT network over the VPN. Server 1 also connected to PANYNJ JSAS. TOC server 2 ran Groove and the Google Earth based

common situational picture" (Lindh, MIO 08-4 AAR Contribution, 2008). This was a successful exhibition of real-time alerts and video (Figure 29) distributed across the entire TNT-MIO network which covers regional portions of Northern Europe and the United States.

Figure 27. Piraya TUSV during MIO 08-4 operations (From Lindh, MIO 08-4 AAR Contribution, 2008)

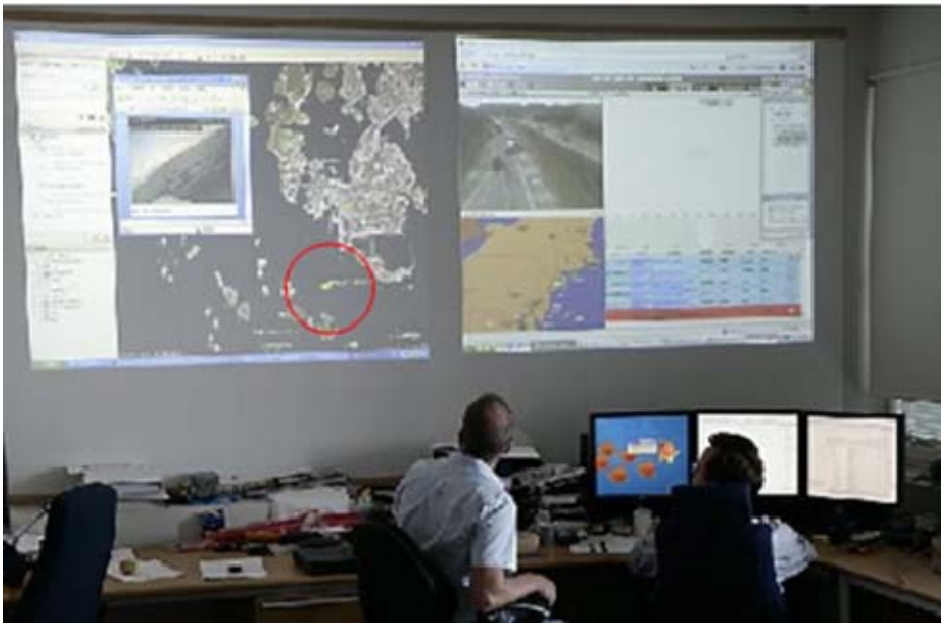

Figure 28. Karlskrona TOC SA view w/ Video, DBFT & JSAS (From Nilsson, 08-4 AAR Contribution, 2008)

Figure 29. Streaming Video from Piraya TUSV
(From MIO 08-4 AAR Draft, 2008)

c. DNTC in Aarhus, Denmark

The Danish Navy Training Center, in conjunction with Systematic, was responsible for the Interdiction phase of European portion of MIO 08-4. They chose to use a software tool called Systematics SitaWare Maritime Boarding Unit (Figure 30), which is a tool with biometrics, evidence gathering, tactical communications, and situational awareness (MIO 08-2 AAR, 2008). In addition, they also employed the TNT File Repository and Microsoft Groove to upload nuc/rad data from their LLNL ARAM equipped drive-by vessel (Figure 31). As with the DBFT software in Sweden, the SitaWare software uploaded CoT data to the TNT Alert server which was subsequently transposed into the NPS SA environment for everyone to observe.

Figure 30. SitaWare Laptop and Fingerprint Reader
(From MIO 08-2 AAR, 2008)

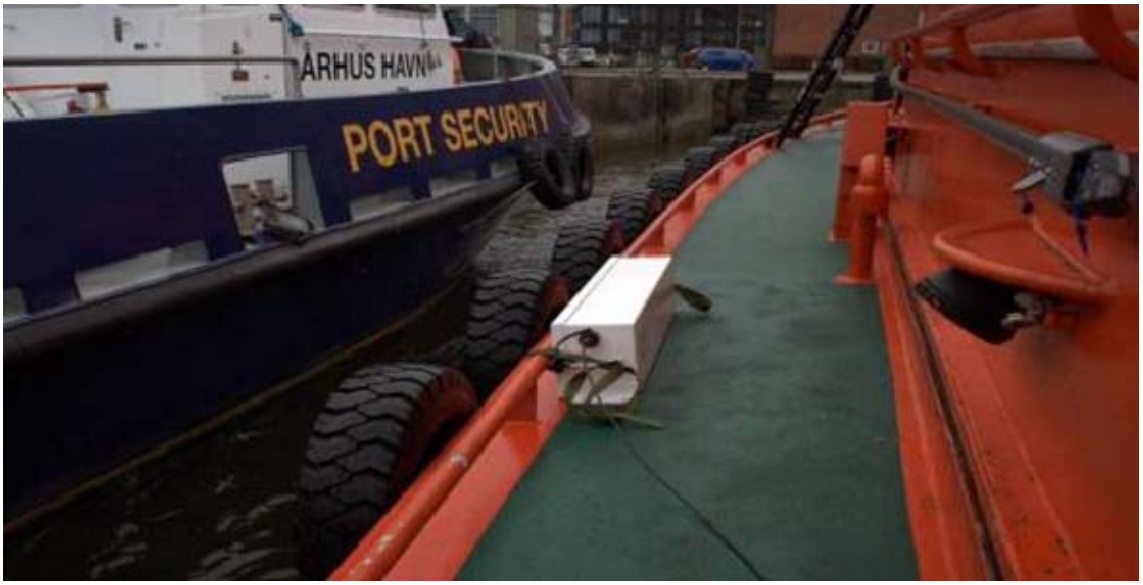

Figure 31. ARAM equipped vessel in Aarhus, Denmark
(From MIO 08-2 AAR, 2008)

In the following experiment cycle, which happened to be MIO 08-4, the Aarhus team took a different direction by exploring the use of sonar to detect SCUBA divers within the Port of Aarhus while simultaneously transmitting CoT data back to the TNT Alert server. They also maintained a connection with the Biometrics Fusion Center in order to query their server regarding persons-of-interest. The map shown in Figure 32 shows the positions of the units during the exercise while Figure 33 shows the Deployable Sonar Command which was set up on the pier. The Command Center was comprised of a RESON Sonar system in conjunction with the Systematic Maritime C^2 System, which is used for collaboration and intelligence gathering purposes much like the SitaWare system which was utilized in MIO 08-2.

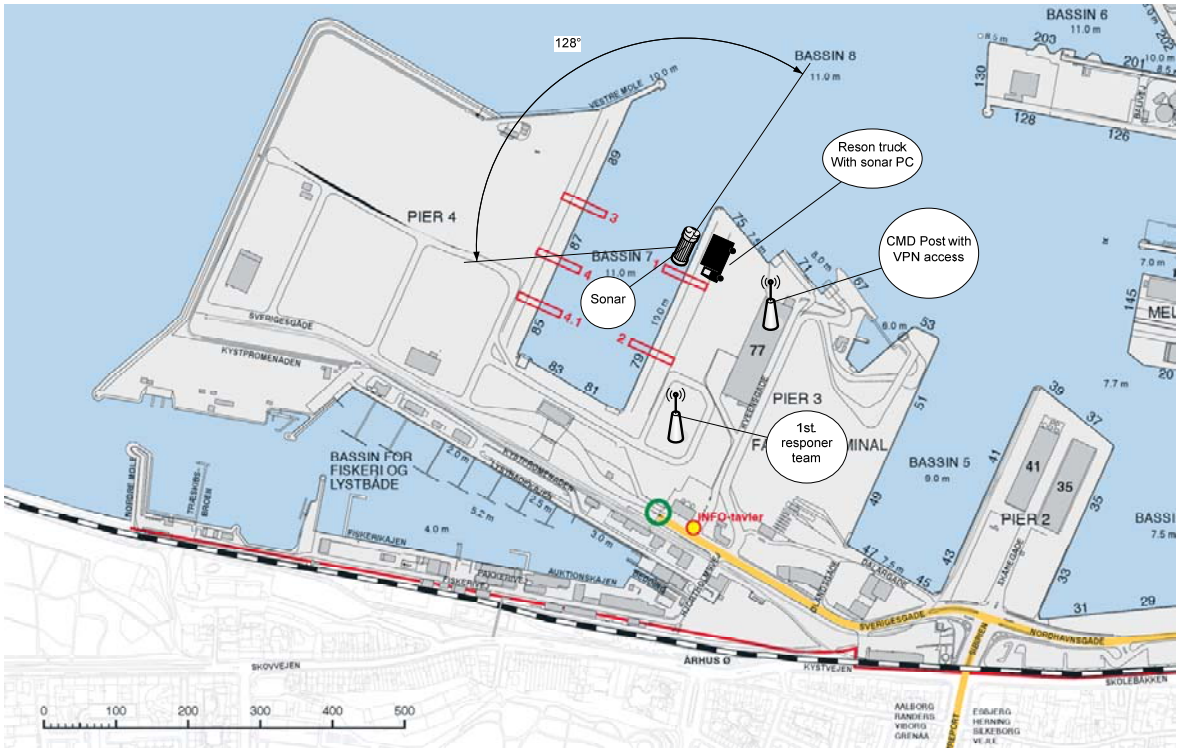

Figure 32. Port of Aarhus Sonar Monitoring AOR
(From Ridderberg, Aarhus Site AAR Contribution, 2008)

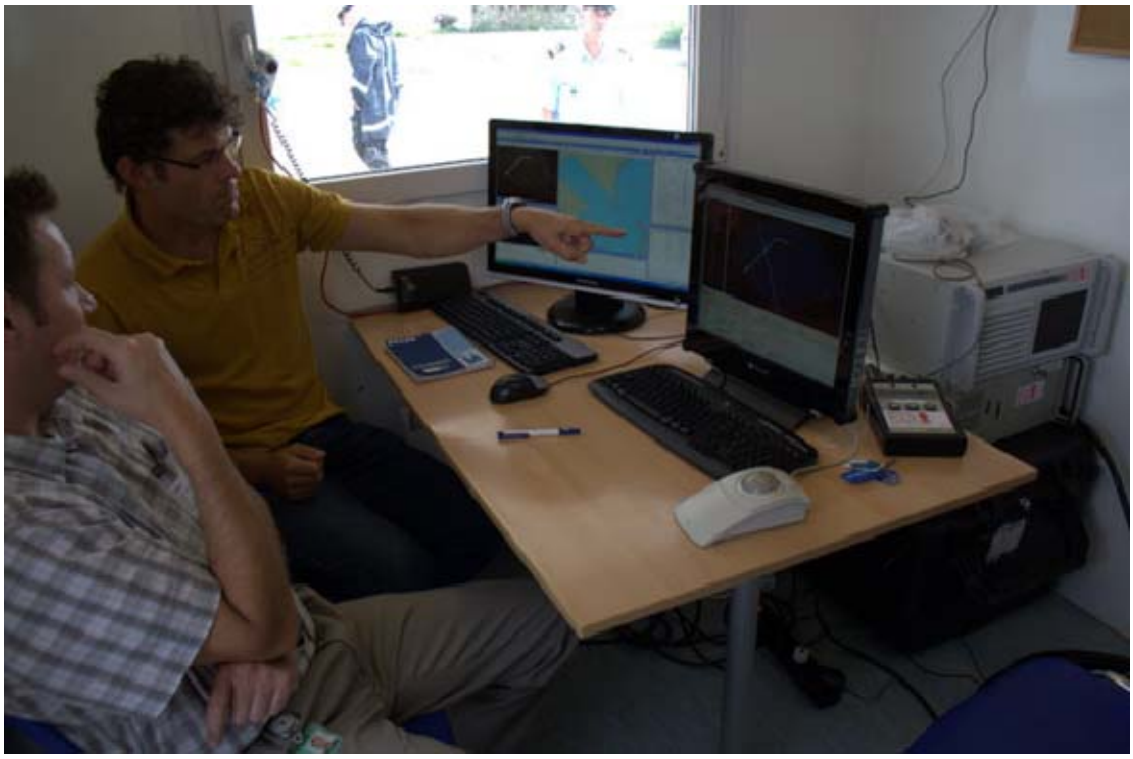

Figure 33. Port of Aarhus Deployable Sonar Command (From Ridderberg, Aarhus Site AAR Contribution, 2008)

As stated earlier, the goal of this scenario was to use Sonar technology to intercept a SCUBA diver within the Port of Aarhus despite the fact that there is normal maritime traffic within the area. The diver is equipped with a closed-circuit re-breather apparatus in order to avoid detection during his dive, as seen in Figure 34. Upon detection a "hostile diver" CoT alert is posted to the TNT server, and a group of first responders are expected to muster at the pier. The first responder team will be equipped with a Systematic Maritime C^2 System, in addition to a Tactical Vest which will provide live video feeds, situational awareness, biometrics, and tactical messaging (Figure 35) (Ridderberg, Aarhus Site AAR Contribution, 2008). Overall, the test was a success despite some

challenges with the Sound Velocity Profiles (SVP) which were affected by nearby high speed ferry vessels and some connectivity problems which were previously mentioned regarding the Biometrics Fusion Center.

Figure 34. SCUBA Diver with Closed-Circuit Re-Breather
(From Ridderberg, Aarhus Site AAR Contribution, 2008)

Figure 35. First Responders equipped with Tactical Vest
(From Ridderberg, Aarhus Site AAR Contribution, 2008)

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IV. COLLABORATION

It was once the prevalent sentiment down at the waterfront that the U.S. Navy Battle Group was meant to be self-sufficient once the last mooring line had been cast off, and the ships had disappeared over the horizon. At that time it was clearly understood that things such as aircraft availability was a function of what you could singularly accomplish onboard the carrier. Concurrently, this philosophy extended to Battle Group (BG) command and control (C^2) and surveillance since so-called national (shore-based) surveillance assets were not trusted in anything other than peace time. The attitude of the time, which is up until the mid 1980s, was one of rugged individualism and a "do it on our own" mentality which was based on the belief that planners within the Washington beltway would not be capable of rendering decisions below the Battle Group level (Kirksey, 1984). This was simply because they were thought to not be technologically capable of managing the assets and intelligence in real time from such a great distance. Times have changed.

In today's Network Centric Warfare (NCW) model, the effects of numerous weapons platforms are massed, rather than the force which must be massed by traditional platform-centric entities to mass combat effectiveness. Because NCW forces are interdependent and act as one they are thought to be optimized versus the "on your own" mentality which previously prevailed. It is believed that this improvement in weapon system employment is a force multiplier, ultimately driving the idea that more accurate

targeting can be done with fewer weapons platforms. (Perry, et al., 2002) This concept is deeply dependent on one pivotal theory, and that is that control of the conglomeration of weapons platforms can be centrally controlled, which calls for a great deal of collaboration by parties not only within the theater of operation, but across the globe.

The preceding chapters in this thesis were put forth to lay the ground work for a better understanding of just how dynamic the CENETIX Field Experimentation Cooperative Program and the TNT Testbed truly are. In addition to the numerous partners and communication platforms which have been exhibited over the past seven years, there has been a continuing theme of extending the boundaries of communication between heterogeneous sensors and nodes. The scenarios and vignettes which are displayed through out the TNT-MIO cycles are intended to most accurately depict the type of ad-hoc and dissimilar networks that could be encountered within any Area of Responsibility (AOR). The ability of the experimental partners to collaborate, or the "process in which a team of individuals works together to achieve a common goal" (Perry et al, 2002), is the subject of this chapter. Each body of work below will be interpreted in regards to its relevance to the most recent experiments and compared to the corresponding trends which have been noted by the author.

A. COLLABORATION STUDY WITHIN CENETIX

1. Klopson & Burdian (2005)

In their graduate thesis titled "Collaborative Applications used in a Wireless Environment at Sea for use

in Coast Guard Law Enforcement and Homeland Security Missions," LCDR Jadon E. Klopson and LT Stephen V. Burdian, both members of the United States Coast Guard, laid out the first extensive look at managing change and collaboration through the experience gathered during their CENETIX research. Their research is a fitting place to begin looking at the trends within the collaborative aspect of the TNT-MIO experiments specifically because they focus on the task of integrating technological change into existing organizations. While this does not fall directly under the purview of communications, the reluctance of stakeholders to embrace new collaborative tools has a direct effect on the perceived validity of a system.

As with all of the military services, the USCG has an aging fleet that does not lend itself well to Coast Guard CIO's vision that states that "The Coast Guard, as the world's premier maritime service, delivers the right information to the right people at the right time" (Nacarra, 1998, as cited in Burdian and Klopson, 2005). It is for this reason that Klopson and Burdian used the example of the Integrated Deepwater System (IDS) transition as their example of the Coast Guard's C4ISR modernization effort. Although the program has more recently been crippled by contractor intrigue and budgetary shortfalls, the initial asset integration, as shown in Figure 36, serves the purpose of these researchers. The overarching theme behind the need for an across-the-board maritime upgrade was to facilitate the precise types of information exchanges which have been at the core of the TNT-MIO

experimentation, to include boarding party communications, real-time biometric capabilities, and Weapons of Mass Destruction (WMD) detection.

Figure 36. Projected Integrated Deepwater System Assets (From Wikipedia.com, 2008)

The previously listed Net-Centric capabilities are core responsibilities of the USCG, and according to Klopson and Burdian, they have been so hampered by the "current slow pace of information feedback that occurs because of lack connectivity, boarding teams have two options when awaiting results of an intelligence check, radiation evaluation, or other information request." As a result of this inability to retrieve intelligence in a timely manner

the crew can either remain on board the subject vessel for an extended period of time, running up very high opportunity cost by not boarding other vessels, or they can depart the vessel. In the event that the requested information comes back warranting further action, the team must relocate and re-board the suspected vessel. While the first option detracts from overall unit effectiveness, the second lends itself to an extremely awkward situation whereas a suspected crew knows they are being reassessed for a reason, resulting in significantly higher levels of hostility and danger for the boarding party. It is no accident that this scenario is performed during every MIO experiment, regardless of location, with the goal of decreasing the amount of time it takes to get the proper intelligence into the hands of the boarding party. Put simply, the shorter the cycle time between information gathering and response, the better the chance to ameliorate both of the potential negative outcomes.

Burdian and Klopson made one astonishingly overlooked observation, and that was that technology is of no use to anyone if it is not utilized. They also reported upon how difficult it is in such a broad organization to get stakeholder buy-in, whether it is from an E-2 Seaman or a “salty” Master Chief Petty Officer. It is precisely for that reason that they discussed the need for an extensive change management plan which lays out eight steps which should prove to be instrumental in carrying out any successful change. (Kotter, 1995, as cited in Burdian and Klopson, 2005). These steps, developed by change management guru, John Kotter, in his 1995 book titled *Leading Change* (“Kotter’s,” 2008), can be seen below in Table 2.

Kotter's Eight Step Change Model
1. Establish a sense of urgency
2. Form a powerful guiding coalition
3. Create a vision
4. Communicate the vision
5. Empower others to act on the vision
6. Planning for and creating short term wins
7. Consolidate improvements and produce more change
8. Institutionalizing new approaches

Table 2. Kotter's Eight Step Model.

While these steps to change within an organization may seem ill fitted to a conversation about collaboration, the two are more in sync with one another than they initially appear. In fact, using these powerful milestones, which Burdian and Klopson applied to USCG communications, one could identify numerous strengths and weaknesses within the collaborative fabric of the CENETIX Maritime Interdiction Operations. To be more specific, the work of these two Coast Guard Officers could be said to have established a sense of urgency by identifying USCG and Homeland Security deficiencies in the wake of 9/11 that could be corrected with sufficient ship-to-ship and ship-to-shore WLAN capabilities. The formation of the CENETIX lab, with its numerous members from governmental, academic, and private sector organizations most definitely represents a powerful guiding coalition, as suggested in step two. Steps three and four are accomplished through the CENETIX vision statement which mandates the exploration of new frontiers in order to support advanced studies in wireless technology (Bordetsky, 2008). It is understood that this vision statement is pliable, which means that if a better idea

comes along then it should be explored. This belief in itself is responsible for taking care of step five, which is to remove obstacles to change and empower everyone to contribute to the stated mission.

It is at this point in Kotter's model that specific TNT_MIO experimental cycles can be taken into account. The planning that goes into each quarterly exercise is quite extensive and it focuses on the collation of a multitude of small vignettes that will all contribute to a larger mission. These smaller scenarios provide short term wins, as dictated by step six, that contribute to the overall morale within the stakeholders. Each success provides an opportunity to build on what went right and identify what could be improved. These successes, as well as problem areas, are recognized during the formation of the After Action Reports and the hope is that the lessons learned will contribute to pushing the boundaries even further in the next experiment, which would correspond with step seven. Finally, step eight contends that changes which are successful should be embedded within the culture of the partnership. The progressive nature of the MIO experiments has shown this to be the case within CENETIX over the past seven years.

This is just a small portion of the comprehensive work that was performed by Burdian and Klopson, as it pertains to the CENETIX experiments. Some of the other areas that they discuss that are important to the field of collaborative studies include the fear regarding the loss of power by previously autonomous combatant commanders, or the big brother theory, and the resistance to technological

change by service members who are content with their present operational configurations. Both of these 'wicked problems' can and should be addressed within the CENETIX environment in an effort to find a solution that could grease the way for a new culture, in addition to new technology.

2. Bordetsky & Friman (2007)

a. Introduction

One of the greatest assets, as was mentioned in the introduction of this thesis, to CENETIX is the participation of military personnel within the experiments. In addition to utilizing the fleet experience of military Officers from around the world as thesis student, Dr. Bordetsky teaches a once-yearly course fittingly titled Collaborative Technologies (IS 4188), from which students produce TNT-MIO related seminars and final projects. According to the NPS student catalog,

> The first part of the course is based on the analysis of collaboration in different human organizations and the requirements to agent-based decision support architecture. The second part of the course is focused on studies of intelligent agents and multiple agent architecture From the beginning of the course students are involved in the hands-on practice with wireless collaborative environments including GPS units, pocket PCs, laptops, and other devices. ("IS4188", 2008).

One of the products of this class, during TNT 06-2 and 06-3, was the work of Creigh, Dash, and Rideout, which was subsequently used in the 12th ICCRTS paper titled "Case-Studies of Decision Support Models for Collaboration in Tactical Mobile Environments" by Dr. Bordetsky and Dr.

Friman. The case study focused on previously described Maritime Interdiction Operations (MIO), High-Value Target (HVT) tracking, and Emergency response coordination scenarios, in which geographically distributed command centers and subject matter experts collaborate to facilitate situational understanding and course of action selection. The main objective for study was to explore the decision making process structure and the communication patterns that could be observed while applying collaborative technology within the selected network-centric tactical scenarios by the participating entities that are depicted in Figure 37. The systematic application of the data gathered to three of the most prevalent military decision support models is discussed in further detail, following a description of each of the models.

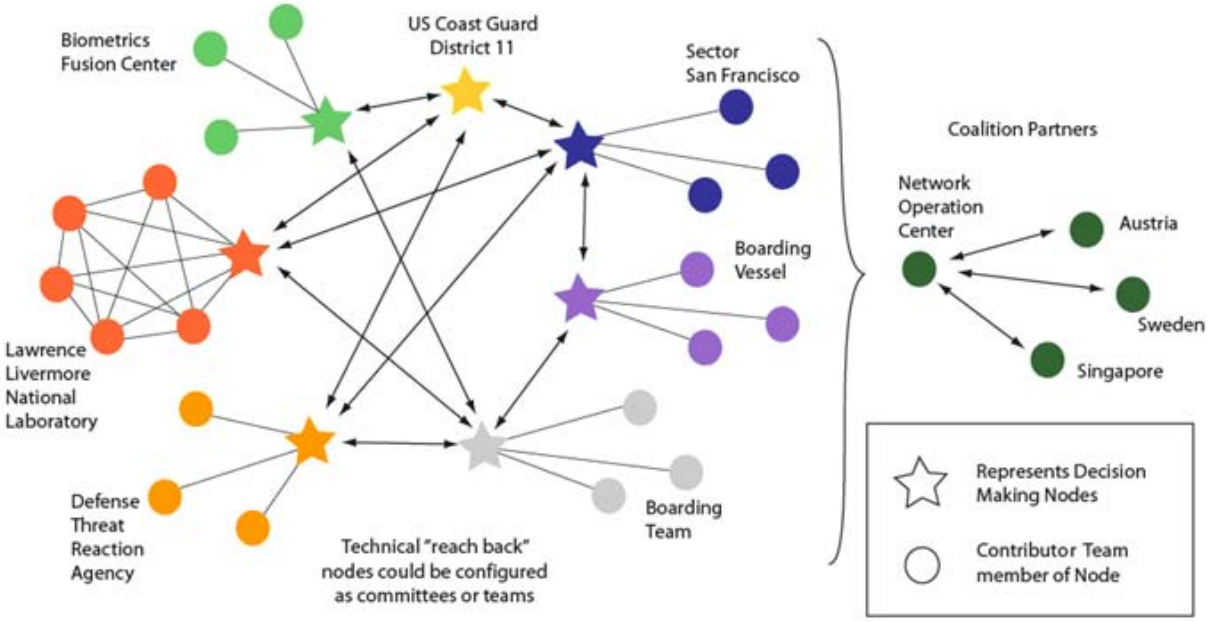

Figure 37. MIO Collaborative Teamwork Model
(After Bordetsky & Friman, 2007)

b. Decision Model Descriptions

(1) Simon's Problem Solving Model - Simon's model, which was presented in 1979 without the implementation step, is comprised of three well known phases, which are illustrated in Figure 38. The model begins with the Intelligence Phase, wherein the decision maker looks for indications that a problem exists; moves to the Design Phase, within which alternatives are determined and analyzed; the Choice Phase, wherein one of the alternatives is agreed upon; and finally the Implementation Phase, where the alternative is put into action (Sprague and Carlsson, 1982, as cited in Bordetsky & Friman, 2007). Bordetsky and Friman put for that this model is capable mapping the entire process and detection and identification of a HVT, although the actual use of collaborative processes required in the iterative decision making cycle is only implicit and needs to be visualized.

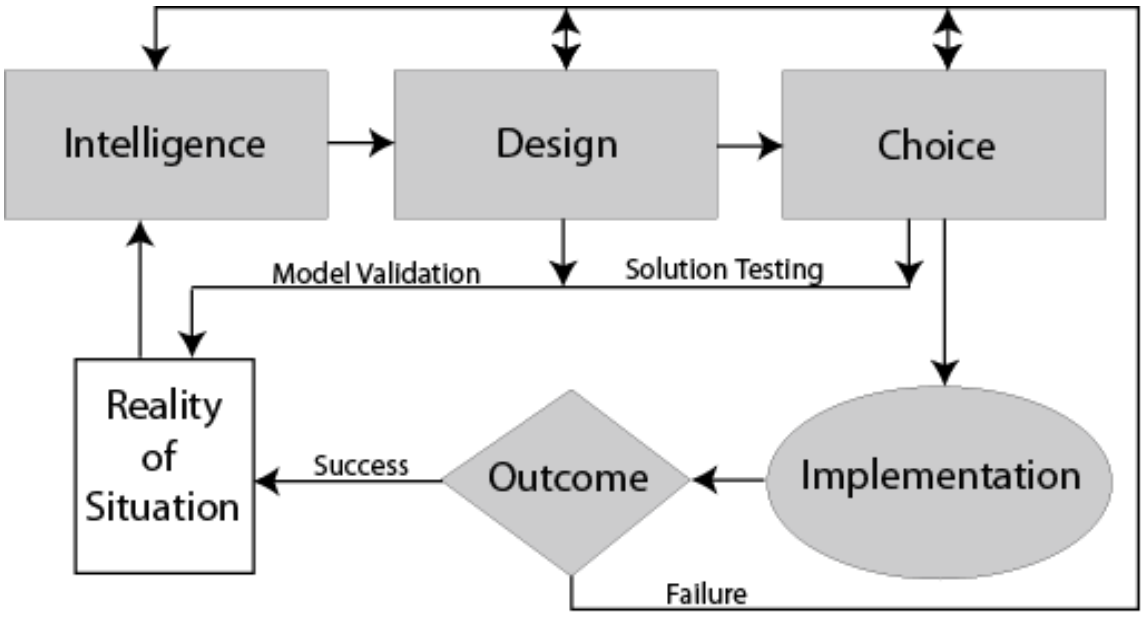

Figure 38. Simon's Modified Problem Solving Model (After Bordetsky & Friman, 2007)

(2) Boyd's OODA Loop - The OODA Loop, developed by USAF Colonel John Boyd, is comprised of four phases – Observe, Orient, Decide, and Act, as shown in Figure 39.

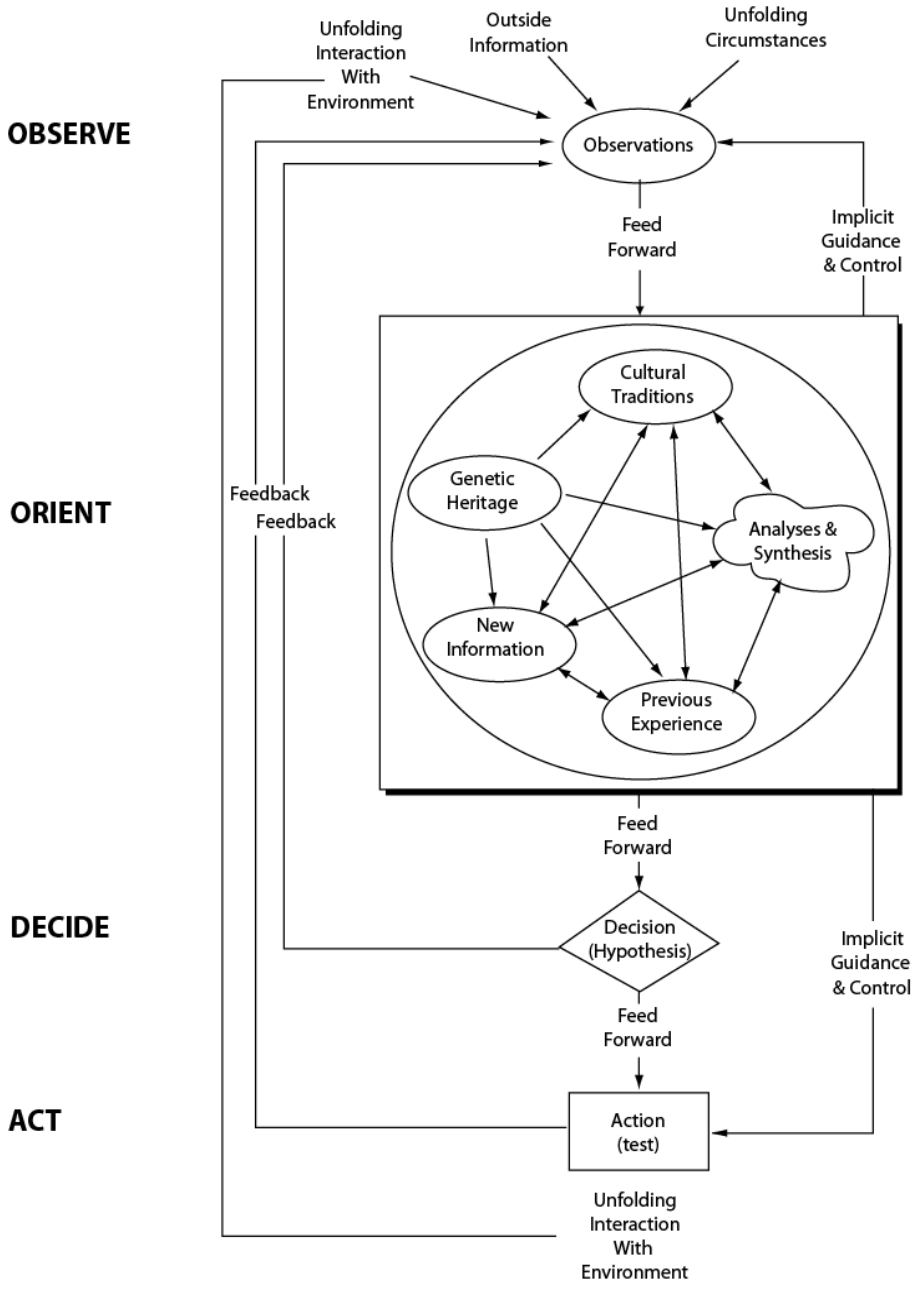

Figure 39. Boyd's OODA Loop

(From Spinney and Conram, 2002, as cited in Bordetsky & Friman, 2007)

Bordetsky and Friman note that the model can not be treated as cyclical and that most decision are based on only two parts of the model – Observe and Act, which misses out on the ever important Orientation Phase. That phase is important as it contributes to the Action Phase that represents the final decision, as well as giving direction to the entire organization toward speeding up the loop in the next iteration. While there are linkages between this model and the HVT scenario, as with Simon's model, the collaborative process is implicit and not clearly emphasized.

(3) Albert's and Hayes' Collaboration Significant Influences Model – Developed in 2006, this model, unlike the other two, does in fact directly include collaboration as an important aspect toward sound decision making (Figure 40). Additionally, the cyclical or hierarchical aspects of the previous two models are broken down, highlighting the strength of an organization as a whole organization working towards a common goal. Bordetsky and Friman explain that this model also maps quite naturally to the experimental setup encountered within the TNT Testbed. This is because the decision making is influenced by an evolutionary 'committee' type structure that is structured around the theory that each individual can be involved in the entire process and enjoy some decision making responsibilities. It is thought that this free flow of information will highlight the collaborative phenomenon that exists within the experiments, flattening an inherently vertical organization into one that better fits into this increasingly horizontal world (Curran and Simmons, 2007).

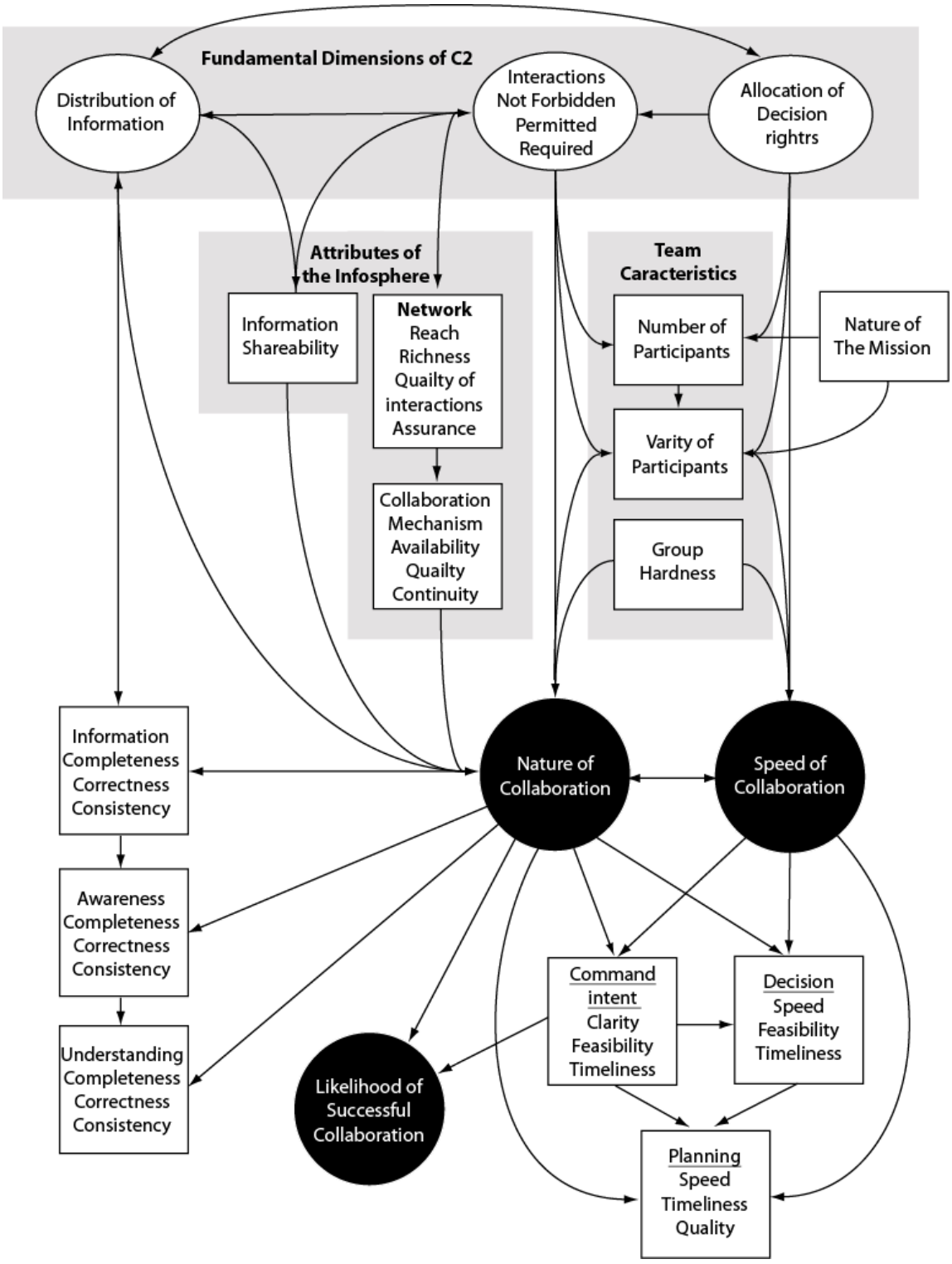

Figure 40. Albert's and Hayes' Model

(From Albert and Hayes, 2006, as cited in Bordetsky & Friman, 2007)

c. Application of Models within TNT-MIO Experimentation

Quantifying the ability of an organization to collaborate is no small task. The effort put forth by the teams of Creigh, Dash, and Rideout, and Pena and Withee produced a product that both intriguing and a significant step toward a better understanding of the phenomenon in general, especially in comparison to the previous work by Burdian and Klopson. While that research was very intuitive, the idea here is to show progress away form broad generalization and more toward comprehension. This should improve the participants' ability to move from simple situational awareness to "situational understanding" (A. Bordetsky, personal interview, October 29, 2008).

In order to apply these military decision support models to the HVT scenario in a way that could provide recommendations for the tactically-oriented collaborative technology tool capabilities the teams took a systematic approach. The teams used many of the resources which have been used within this thesis, to include After Action Reports (AAR), Executive Summaries, and interviews with resident experts. To obtain qualitative and quantitative statistics, in regards to collaborative technologies (CT), a Lickert Scale was developed with common "score" descriptions that ranged from 1-10. This scale succeeded in degreasing individual subjectivity, as well as facilitating the statistical analysis. Using this scale, a spreadsheet was developed and each member applied the 1-10 scale across the pre-selected components from the three models for all 25 MIO events. These numbers were automatically averaged by

the spreadsheet in order to determine which model was the most appropriate, or if none was singularly successful, to develop a hybrid decision model.

Although each model has its strengths and weaknesses, it was discovered that the hybrid model would have to be proposed that would combine elements from all three of the decision support models, taking into consideration the need for collaboration, but still allowing an individual to make a solo decisions. This was because, when directly applied to the HVT model, the Boyd and Simon models did not lend themselves to the initial setup of the network and the Albert-Hayes model did not have an execution phase, nor did it fully exploit the synergy developed during the collaborative process. As a consolation it was agreed upon by both groups that the intent of this group would be to develop a model most closely aligned with Simon’s model simply because it was believed to be more robust than Boyd’s model and not as complex as the Albert and Hayes iteration.

The product of this decision, shown in Figure 41, combines the best features from all of the models while better incorporating collaboration and execution after a decision is made. Although this model is quite complete, especially considering the large body of knowledge that it covers, it still lacks a proper answer to the question of synergy and collaborative ties, which will be properly addressed in one of the proceeding visits to this subject by one of Dr. Bordetsky’s PhD students, Richard Bergin, in the next chapter.

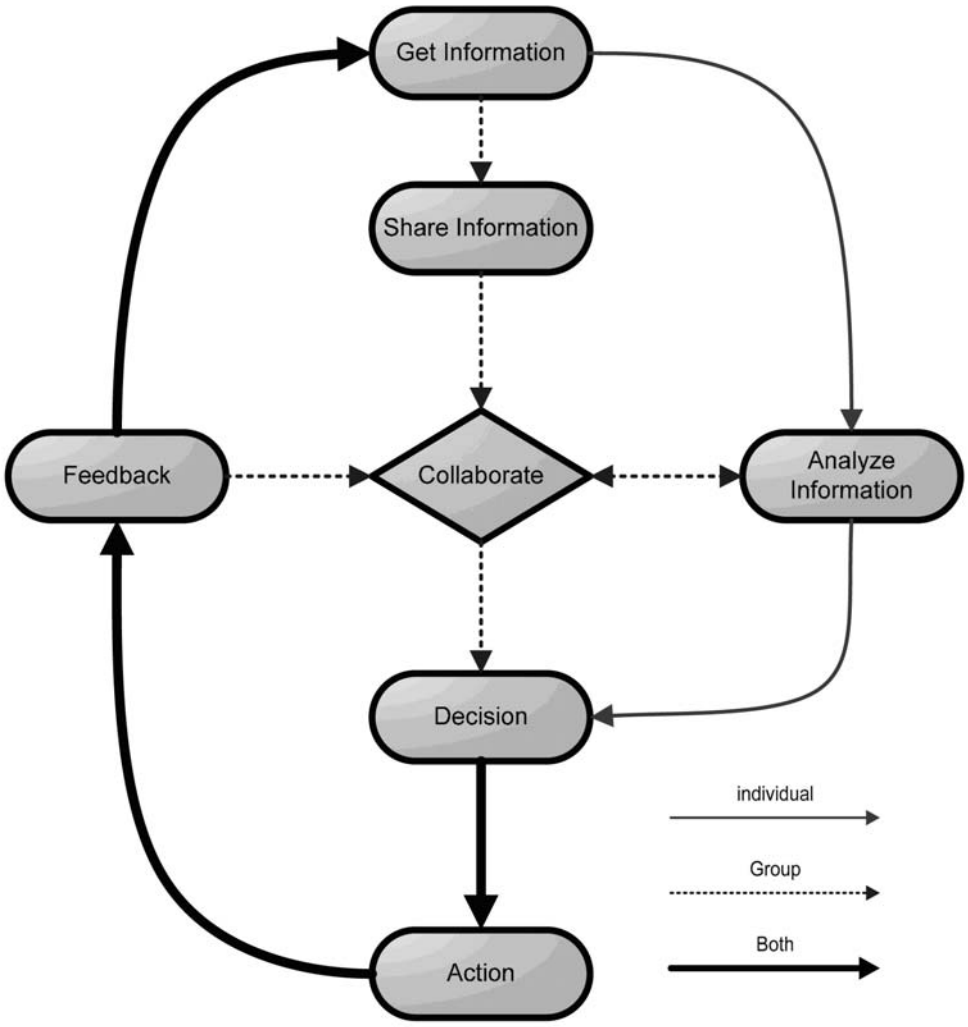

Figure 41. Collaboration Model Proposed by MIO Study Team (After Bordetsky & Friman, 2007)

3. Hudgens (2008)

Expanding upon the collaboration research done by Bordetsky and Friman is Lt Col Brian Hudgens, USAF, and his paper titled Feedback Models for Collaboration and Trust in Crisis Response Networks. His approach to collaboration and trust in crisis response networks directly contributes to a better understanding of interactions and relationships in both established and ad hoc networks. His extensive literature review uncovered many trends regarding the

assembly of unrelated organizations working toward a common task that pertain directly to the hurdles that have been experienced within the CENETIX Field Experiment Cooperative and the TNT Testbed, most notably the issue of having members with a common task, but differing constraints. (Stephenson and Schnitzer, 2006, as cited by Hudgens, 2008). The hallmark of the TNT-MIO experiments is the combination of heterogeneous organizations that are, as Hudgens explains, exploring ways that they can engender coordination through the use of feedback loops.

Using the fundamental components of systems theory, which include a series of feedback loops, identified as a "circle… of cause-effect relationships" (Senge, 1990, as cited by Hudgens, 2008), Hudgens attempts to find the middle ground between trust, communication strategies, and the commitment of resources. Trust is identified as a relationship governance construct that manifest itself as the expectation by one party that another party is both credible (reliable) and benevolent (Moorman, Zaltman, and Despande, 1993; Morgan and Hunt, 1994, as cited by Hudgens, 2008). The second construct, communication strategy, is comprised of frequency, direction, modality, and content of communications, which can affect both qualitative and quantitative outcomes (Mohr and Nevin, 1990, as cited by Hudgens, 2008). Finally, it is asserted that the coordination among organizations is positively affected by the commitment of needed resources toward the common goal. This seems reasonable as it resembles a symbol of 'good faith' to all parties involved, eventually perpetuating a cycle of more trust, more communication, and more resources by all participants.Possibly the greatest contribution by

Lt Col Hudgens to this thesis was his explanation, borrowed from Stephenson and Schnitzer (2006), of the progression of two organizations from initial contact to a full fledged partnership. It should be noted that this example only contemplates two entities for the sake of simplicity. Consider if you will, that an organization (Org 1) signals another credible organization (Org 2) by committing resources toward the amelioration of a crisis situation (the shared goal). This commitment of resources may involve any number of observable investments, such as the construction of a communication network where none exists or providing a real or virtual shared workspace. Org 1 may also volunteer intelligence about the crisis to Org 2 and seek advice on a proposed course of action to solve the problem. Org 1's credibility ("we are devoted to this common goal and willing to provide resources") and benevolence ("we will share our intel and resources with you, and your opinion matters to us") is subsequently developed as a result of the resource commitment, along with the initial collaborative communication strategy.

As demonstrated in Figure 42, this engendered trust should result in Org 2 becoming more committed to working more closely with Org 1 to address the crisis, which is demonstrated by a reciprocal investment of resources. Org 2's behavior, in return, signals its credibility and benevolence to Org 1, completing the feedback loop and resulting in greater coordination. Hudgens refers to this pattern of events as a "virtuous" feedback process. His warning that this relationship could be functionally constrained by environmental factors, such as infrastructure and physical scope directly correlates with

the concerns of the CENETIX leadership during geographically dispersed interorganizational experiments.

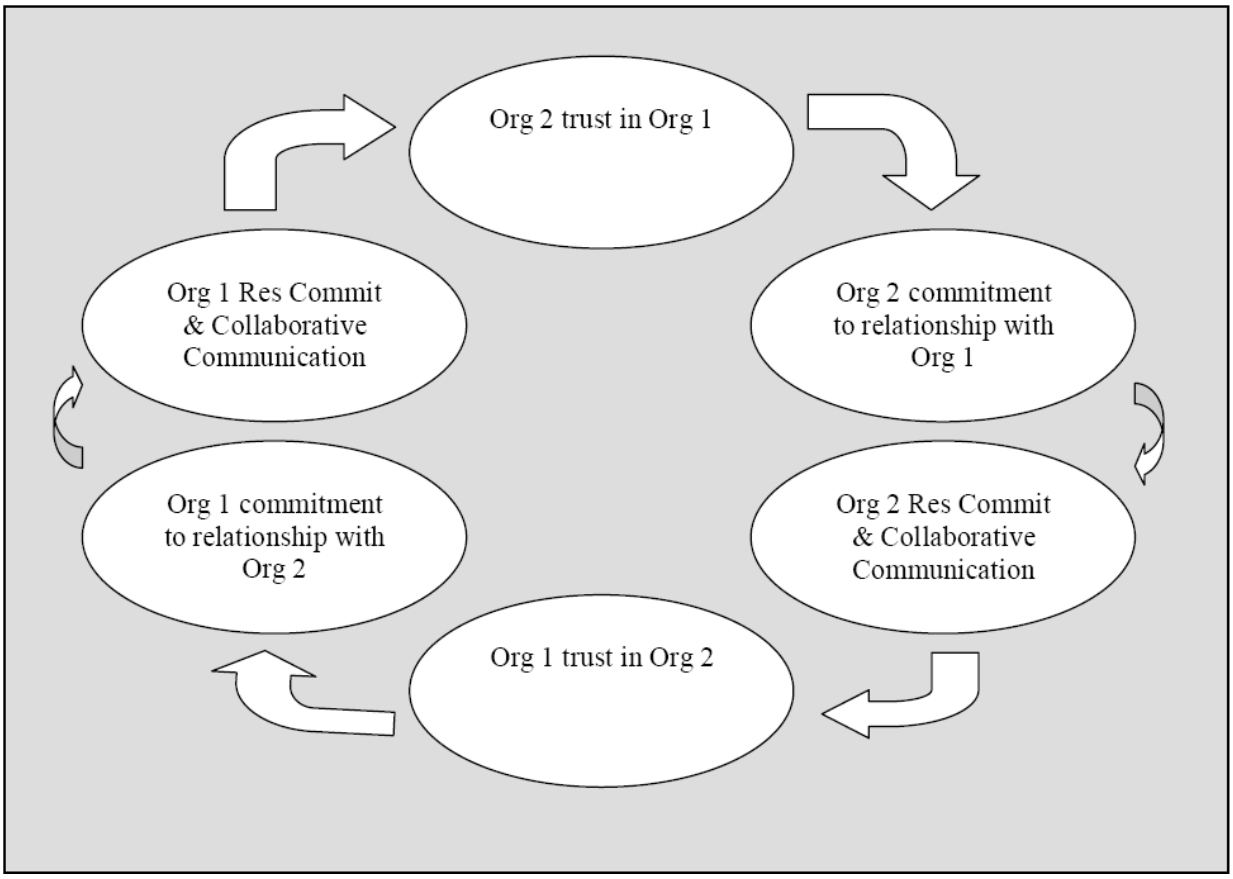

Figure 42. Virtuous feedback process
(From Hudgens, 2008)

If one was to go back and examine the partnerships within the TNT-MIO experiments they would find that this drive toward virtuosity is precisely how many of the relationships were developed. It could also be inferred that the progression that many of the initial observers took on their way to becoming primary participants, as was described in chapter three of this thesis. The concept that a feedback loop comprised of reciprocal resource commitments and compelling communication strategies can

engender a larger degree of trust and commitment between organizations and develop stronger ties is valid and reproducible.

4. Bergin (2008)

The underlying theme within all of the reviewed works within this thesis has been the desire to resolve the problems that are inherent to collaboration between distributed entities. The newest work on the subject, from within the CENETIX community, comes from Mr. Richard Bergin, and is titled “Collaborative Network Topology Adaptation: Creating New Synergies”. Bergins paper may be the most be the most comprehensive work to date that deals directly with the concept of links and synergy within disparate groups, while intuitively asking the questions that may finally bring true collaborative change to the experiments. This research is specifically based upon the scenarios and correspondence encountered during the most recent MIO 08-4 experiment cycle. As stated throughout this thesis, that particular scenario revolved around the identification and tracking of a possible radiological dispersal device (RDD) at several areas along the Eastern seaboard, to include the Port of Newark, New Jersey.

Just as with the previous work from Lt Col Hudgens, Bergin’s work approaches the wicked problem of large-scale networking initiatives from a systems theory perspective. The work focuses on what he refers to as Synergies of Scale, Division of Labor, Functional Complementarities, Synergies of Information Sharing and Collective Intelligence, and Synergies of Tool and Technology (Corning, 2007 as cited by Bergin, 2008). It is no accident

that these terms are familiar, as they correspond a great deal with the relationship governance constructs discussed by Hudgens. In the case of the Bergin work, the goal is the observation of the development and morphing of weak and strong ties within the experiments. For the purpose of his study, Bergin defined weak ties as those that did not exist prior to a particular scenario within the MIO experiment, particularly where reciprocal services between two nodes did not exist prior to the field study. Strong ties are defined naturally the relationships that have been subject to reciprocation before the experiment had been established. Hudgens' example would say that the strong ties would be a product of virtuous feedback process. It is Bergin's assertion that, when one considers their "circle of friends", they are less likely to get new information from the closest friends because of similar thought patterns and experiences, while people outside of that circle, or weak links, and provide a new perspective. It is for this reason that although strong links may seem the most beneficial, new weak links could ultimately breathe fresh air into an existing problem resolution.

The concept of ties, in the case of CENETIX, is illustrated by Figure 43, which shows a greatly simplified version of the network topology during MIO 08-4. Using this graphic it is much easier to understand the difficulties that are brought about by utilizing such an incredibly diverse range of platforms, sensors, and geographic locations. These ties, which are expected to be of both the weak and strong variety, draw on numerous concepts that

include trust-based social capital, expertise location, goal congruence, anticipation of value, access to parties, and absorptive capacity.

Radiological Interdiction and Command Center Communications

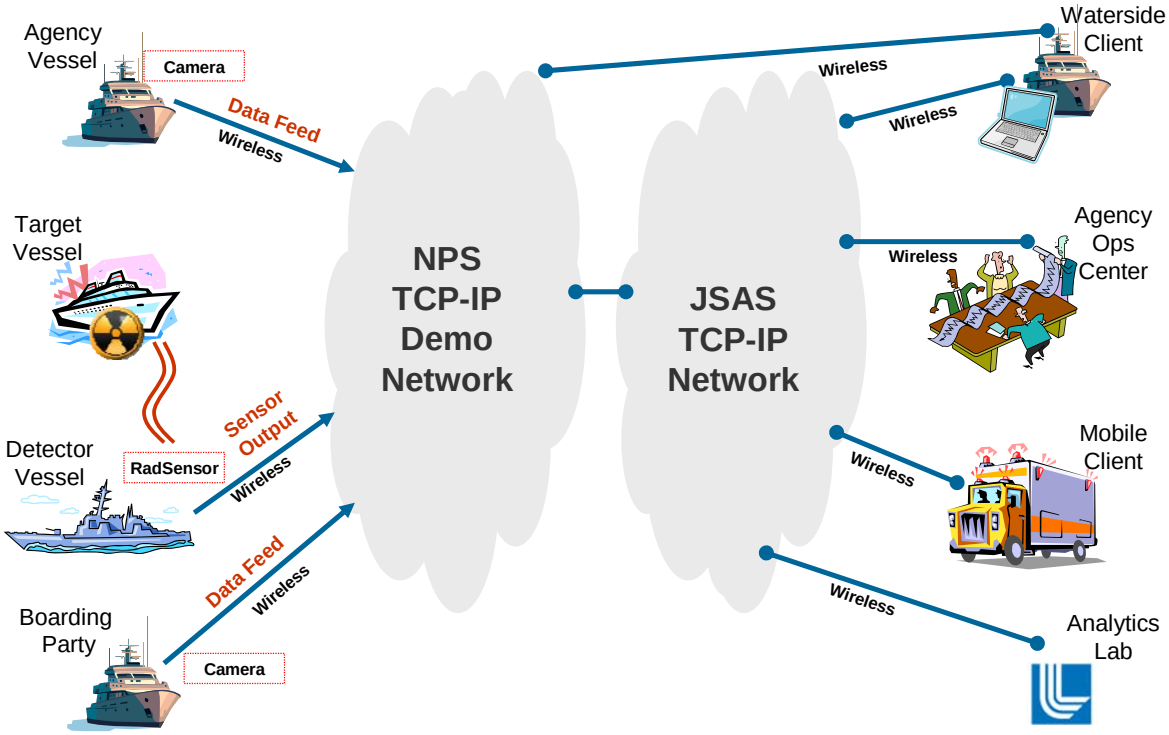

Figure 43. Simplified 08-4 MIO Links & Nodes
(From Poulsen & Bordetsky as cited by Bergin, 2008)

While goal congruence and expertise location have been previously discussed within this thesis, the concept of absorptive capacity is a new topic. "Absorptive capacity refers to the ability to recognize the value of new knowledge and information, and to assimilate and use it (Cohen and Levinthal, 1990 as cited by Bergin, 2008). Bergin uses the magic rule of seven ±1, developed by Miller, to describe the limitations that human cognitive

factors play within the node capacity calculation (Miller, G., 1956 as cited by Bergin, 2008). Much as with the trust discussion earlier, Szulanski's findings are that additional factors constraining absorptive capacity within an adaptive collaborative network is the recipient's lack of absorptive capacity, casual ambiguity, and arduous relationships between recipient and the source (Szulanski, G., 1996 as cited by Bergin, 2008).

The ultimate goal of this thesis, and of the work by Bergin, is to enable network enabled participants to get information to decision makers in the fastest possible manner so that they can determine a well informed course of action. Bergin puts forth that this will more readily be accomplished with a better understanding of the mechanics behind relationships and interactions. The correlation between interpersonal and swift (ad-hoc) trust and strong and weak links, respectively, is more than practical, it is highly intuitive, leading one to believe that this may be simpler than it initially appeared. As stated earlier, the final parsing of the data gathered by Bergin during this latest experiment, filtered through the understanding that morphism is a part of everyday life, as well as collaborative experimentation, could be the most revealing and enlightening perspective to come out of CENETIX to date.

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V. CONCLUSION

> *We can no longer depend on overwhelming our enemies by brute force… with weapons technology. While we may be outnumbered, we are moving to new concept involving maneuvering, imagination, guile and finesse, supported by advanced technology. It is a wartime function which must be intact in peacetime and ready to function in war.*
>
> *Dr. James H. Babcock (1980)*

A. MAJOR CONCLUSIONS FROM RESEARCH

In an era of mind-boggling technological advances, both in terms of wireless communications and situational awareness, new ways of managing the barrage of information thrust upon the tactical operator are becoming ever more important. Traditional approaches that prospered because of the military advantage within the realm of Command and Control (C^2) and tactical communications have been negated to some extent by the ability of both rogue nations and organizations to develop solutions using commercial off the shelf (COTS) devices. The challenges of a collaborative environment, in combination with the task of dealing with less than perfect service quality in networks where the set of available resources change on the order of minutes, not months, (Clement, 2007) demands that a new paradigm must be developed if we wish to succeed. The work produced by the team of Klopson and Burdian was a phenomenal first step and the papers written Bergin, Bordetsky, Hutchins, and Hudgens have all made substantial contributions, but the fact remains that the art of collaboration in the digital realm is still in its infancy.

The specific aim of this thesis is to illuminate and address the collaborative advances that have been achieved through the Center for Network Innovation and Experimentation during the past seven years, while identifying the specific trends within that research. The concept of having the benefit of remote experts directly participating in the CENETIX Maritime Interdiction Operations model, which was developed by Bordetsky, Dougan, and Dunlap, has gone from a patchwork of disparate technologies to a mesh-enabled feedback loop that is no longer limited by the number of participants and observers, but by the ability of facilitators to keep everyone abreast of the capabilities brought to the experiments by new partners. Bergin would refer to this as the need to address the participants' ability to integrate weak ties into an environment that has been built upon a base of extremely strong ties. The strong ties that the TNT-MIO experiments are bound by are from node and network perspective.

As would be expected with any research endeavor, the level of understanding has dramatically increased, mainly because of the real-world nature of the scenarios that are developed by the CENETIX researchers and partners. The addition of more scripted avoidance schemes may be all that it will take to truly prove the relevance of the experiments. That topic will be discussed below in the suggestions for the future.

1. Areas of Success

The success stories within the CENETIX partnership are numerous and varied. From a collaboration stand-point, the ever-evolving nature of the SA environment has contributed

greatly to the success of the experiments. The expertise garnered from Eugene Bourakov, in the arena of SA development, to fit the dynamic needs of each experiment, is deserving of the most praise. Additionally, his groundbreaking work in the area of Self-Aligning OFDM (SAOFDM) antennas has been remarkable and of interest to almost every new partner within the experiments. The adaptability of these antennas has meant that we have barely scratched the surface of their capabilities. It is known that these antennas provide the missing link in reachback in one of the most promising areas of success for the MIO experiments, and that is the self-forming capability that has been exhibited by the mesh networks within the most recent maritime operations. This ability has successfully extended the network in a holistic manner between nodes in an automated manner that was not previously possible (TNT-MIO 08-2 AAR, 2008).

During the utilization of the above mentioned network, the participants of the experiments have also improved their ability to work across multiple application platforms simultaneously, such as Groove, CENETIX SA, and JSAS. There is some concern, which will be discussed below, that there is a need for more automation and sharing between these particular programs. This comes specifically because of the way the programs are used as a backstop for one another. For instance, if the Groove server were to become unresponsive, the observers and participants would migrate to VC1 and the File Repository, and continue the experiment. This method of transitioning from program is not readily clear to new partners, such as was the case with the PANYNJ team during MIO 08-2, but upon

clarification and training it becomes a part of the experiment procedures. This method of moving from program to program is not optimal, but it does generally produce the desired results without completely stopping an experiment in its tracks.

2. Areas for Improvement

In what may appear as a bit of a contradiction, the ability to communicate simultaneously across multiple platforms, which was described as a CENETIX strength, is also one of the areas most in need of more attention. The time critical nature of the information that is sent during the experiment cycles is too easily put in jeopardy by a lack of common understanding about the procedures and network criteria that can cause a change in collaborative tool workflow. Many of the moves from one product to another are a result of network connectivity problems that are too easily misdiagnosed as a result of inadequate network performance data. As one of the primary Research Associates involved in the TNT-MIO project, Michael Clement stated that within network-centric operations, “the task of mapping every link within a single highly mobile unit, let alone the complex interconnections between join and coalition forces, would take a heroic effort.” (Clement, 2007). Numerous products have been used in an effort to maintain the reliability of the network, in turn increasing the efficiency of collaboration within the Testbed, but there is still room for improvement.

There are areas that are not specific to our experiments such what Mercado referred to as the separation of tasks within the Tactical Operations Center (TOC). In an

effort to encourage participation by all parties, and as a result of unclear directions about the platform switches mentioned above, there is the possibility for a lack of queue discipline. Perry describes this as the phenomenon wherein a seemingly undisciplined network produces extraneous comments as a result of all participants erroneously feeling that their comments are critical, when in fact they are merely observations that should be recorded outside the primary communication channel (Perry et al., 2002). This problem, now that it is recognized, has been addressed to some extent by predetermined protocols and the designation of a single person to regulate communication.

B. FUTURE RESEARCH RECOMMENDATIONS

1. Collaborative Tool Integration

In the years since the TNT_MIO experiments started there have been any number of collaborative tools used in an attempt to find a tool that could satisfy the needs of all of the stated desired tactical missions. The most recent incarnation of this desire is the use of the web portal, such as the Joint Situational Awareness System (JSAS) developed for the Port Authority of New York and New Jersey. It was determined during the MIO 08-4 experiment cycle, despite a preconception that JSAS would be able to provide the needed SA, that PANYNJ was still in need of numerous CENETIX tools that had previously been proven as effective. In this specific case, JSAS lacked the ability to display MIO specific intelligence that was readily provided by the NPS Situational Awareness environment. (A. Bordetsky, personal interview, October 29, 2008). The

previously noted need for an integrated tool or the ability to automate the interaction of the current toolset is still in need of a solution.

2. Data Sharing Alerts

The current network configuration, which includes the presence of remote experts in rad/nuc identification and biometrics consolidation, determines that numerous tools are necessary to perform the stated duties during Maritime Interdiction Operations. In light of that fact it is imperative that a method be developed to adapt the alerts that are set forth by each tool into a common application or portal that is automatically populated. This solution should be developed as a result of an investigation into which variation of this tool could serve the greatest number of the participants. Included in the criteria should be a method to provide this functionality in a 'lite' form that would be functional at the Boarding Officer level.

3. Detection of Target in Avoidance Mode

The ability of MIO participants to detect targets that are pre-designated in a geographical area has increased dramatically, as seen in experiments all the way up through MIO 08-4, but the area that warrants further research is the detection of dynamic sources, or those that are attempting to avoid discovery (A. Bordetsky, personal interview, October 29, 2008). The detection of an actual radiological dispersal device would demand that the ability to discover a nuclear agent as it passed a sensor, as was proven using ARAM in MIO 08-2, and the added ability to follow the suspected delivery vehicle to its destination if

it were not in fact stopped and tagged. This area of research would be of special interest to metropolitan protection forces, such as those in the New York City area, where an activated sensor in a tunnel heading in or out of the city or past a buoy in the harbor area only verifies that a suspected agent passed the sensor. Instant communications to local authorities in a manner that coincides with remote experts would be an immense step in the right direction.

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