

14TH ICCRTS

C2 and Agility

**TNT Testbed for Self-Organizing Tactical Networking and
Collaboration**

Track 2: Network and Networking

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Introduction

Beginning in 2002, a team of Naval Postgraduate School researchers together with sponsors from USSOCOM, and later joined by the OSD and DHS S&T Programs, started a new campaign of discovery and constraints analysis experiments (Alberts and Hayes, 2007), which is now collectively known as Tactical Network Topology (TNT) Experiments. This campaign of experimentation, carried out under the USSOCOM-NPS Field Experimentation Cooperative program and OSD/ HLS S&T support unfolds in two major areas.

The first one involves quarterly field experiments with USSOCOM, in which NPS researchers and students as well as participants from other universities, government organizations, and industry investigate various topics related to tactical networking with sensors and unmanned aerial systems (UAS) as well collaboration between geographically distributed units with focus on high value target (HVT) tracking and surveillance missions. The TNT experimentation process with USSOCOM is focused on both technologies associated with networking and the human aspects of networked forms of organization. Technologies investigated have included network-controlled UASs, various forms of multiplatform wireless networking, mesh networked tactical vehicles, deployable operations centers, collaborative technologies, situational awareness systems, multi-agent architectures, and management of sensor-unmanned vehicle-decision maker self-organizing environments.

The second direction involves Maritime Interdiction Operation (MIO) experiments with Lawrence Livermore National Laboratory, USCG, First Responders (San Francisco Bay, New York/New Jersey) supported by HLD and HLS S&T Programs and DoE agencies. These experiments are conducted twice a year and are also supported by the overseas partners from Sweden, Germany, Denmark, and Singapore.

In all of these experiments, the focus has been on both adapting both emerging and commercially available technologies to military requirements and on investigating new social networking/collaboration elements associated with the addition of such technologies to the battlespace and maritime security operational scenarios.

In the core of TNT HVT and MIO experimentation is a unique testbed, which enables sustainability and evolution of the TNT experimentation campaign. It is based on the plug-and-play tactical-on-the-move sensor-unmanned systems networking capabilities combined with global reachback to the remote expert/command sites and augmented by rapid integration applied research services.

The goal for this paper is to describe the architecture of the TNT testbed environment and the potential for its application to studies of emerging self-organizing tactical networks.

1. Tactical Networking Testbed: Man-Machine Plug-and-Play Systems Enabling Sustainable Experimentation

Each quarter, the growing team of NPS researchers, USSOCOM operators, and commercial/academic partners get together on the grounds of Camp Roberts, California to explore synergy and impact of emerging sensor-unmanned systems-decision maker self-forming networks on to the HVT and ISR missions. Figures 1a and 1b illustrates the state of the experimentation team during FY2008.

Large Interdisciplinary NPS Team	Programs Utilizing TNT Testbed
27 Thesis Students 31 Faculty, 4 Staff; 9 Departments and Institutes Includes 21 PhDs Course Projects: IS, OR, MET 28 NPS Field Experimentation Projects	AFRL JASMAD JIEDDO AFRL Marti MCWL TW Radio AFRL N-CET Team TACLAN AFSOC CP/BI JFCOM EC-08

Participating Universities	
ASU	Univ. of Bundeswehr - Munich
Carnegie Mellon	Univ. of Florida
Case	Virginia Tech
JHU/APL	WPI
MIT	WVHTF
NDU	UM, Columbia, UCSD, UCCS
UC Berkeley	

Figure 1a. TNT Academic Participants for FY08

Foreign Country Participation in MIO			Broad DoD and Gov't. Participation and Support		
Univ. of Bundeswehr at Munich			- USSOCOM		
Swedish Naval Warfare Center			- AFSOC		
Turkish Air Force Academy			- MARSOC		
Systematic/Danish Navy Training Center			- USASOC		
			- NAVSOC		
			- JSOC		
			Other Participating DoD and U.S. Gov't.		
			AFRL	LLNL	SPAWAR
			ARL	NAWCWD	TSWG
			BTF	NECC	USASMDC
			DARPA	NIST	USCG/D-11
			DHS/S&T	NRL	USCG-Staten Island
			DNDO	NSA	USMC-HQMC
			DOE RAP	NSWCCD	USMC-MSTSSA
			DTRA	ONR	USMC-MCWL
			JFCOM	ONR 113	USATC (Fort Eustis)
			JIEDDO	OPNAV N8F	
			JITC	OSD/HD	
			LBNL	OSD/RRTO	

National Guard	
West Virginia – Camp Dawson	
Indiana – Camp Atterbury	
State and Local Government in MIO	
Alameda County Sheriff's Office	
Oakland Police Dept.	
San Francisco Police Dept.	
Port Authority of NY/NJ	
Fire Department New York	
California Office of Emergency Services	
California Dept. of Health	
U.S. Park Police	

Figure 1b. TNT Testbed Federal, Local, and Foreign Participants in 2008

The TNT experiment members plug-in their sensors, networks, UASs, aerial balloons, ground vehicles, situational awareness systems, and operator units into the TNT testbed comprised of segments and layers.

These field experiments are then connected back to the Network Operations Center (NOC) at NPS via an 802.16 network link. All the network infrastructure involved is operated and maintained by students and is, itself, often the subject of some experimental activity. High-level network views of a few of these sites are given in Figures 2 and 3.

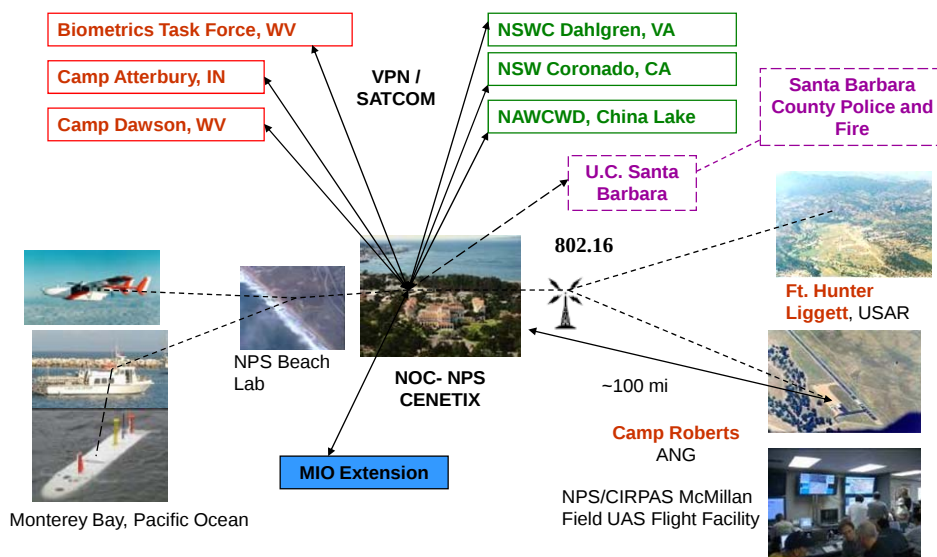


Figure 2. Plug-and-Play Testbed with Global Reachback: Camp Roberts segment with reachback to East Coast Centers

Figure 2 shows the fixed wireless 802.16 backbone connecting NPS with Camp Roberts. It reflects the complexity of the TNT network setup. The Light Reconnaissance Vehicle (LRV) in Fig. 3 is a mobile OFDM¹ node. Also visible are a number of remote field locations that have been used in past experiments. In addition to the locations at Camp Roberts and NPS, various remote sites are connected to the TNT infrastructure via an ever-changing set of Virtual Private Network (VPN) tunnels on top of satellite links or commercial IP cloud. As such, a large portion of each experiment is concerned with the collaboration and coordination necessary to integrate the large number of sites and interested parties into the ongoing activities.

For example, the Biometrics Fusion Center (BFC), located in West Virginia, has been a member of many of our experiments. They are concerned with our research as a way of connecting remote, tactical field users to biometrics databases removed from the battlefield. In this manner, field agents looking for suspected terrorists can take sensors (fingerprint, facial recognition, etc.) directly to the area of interest while drawing on the full (and likely updated) databases provided by the BFC. Conversely, information gained in the field can be immediately made available to analysts back at headquarters or located in other locations around the world. Figures 3 and 4 illustrate the self-forming mesh segments of TNT testbed at work with the UAS systems and different applications.

¹ Orthogonal Frequency Division Multiplexing — this is the technology that underlies 802.16.

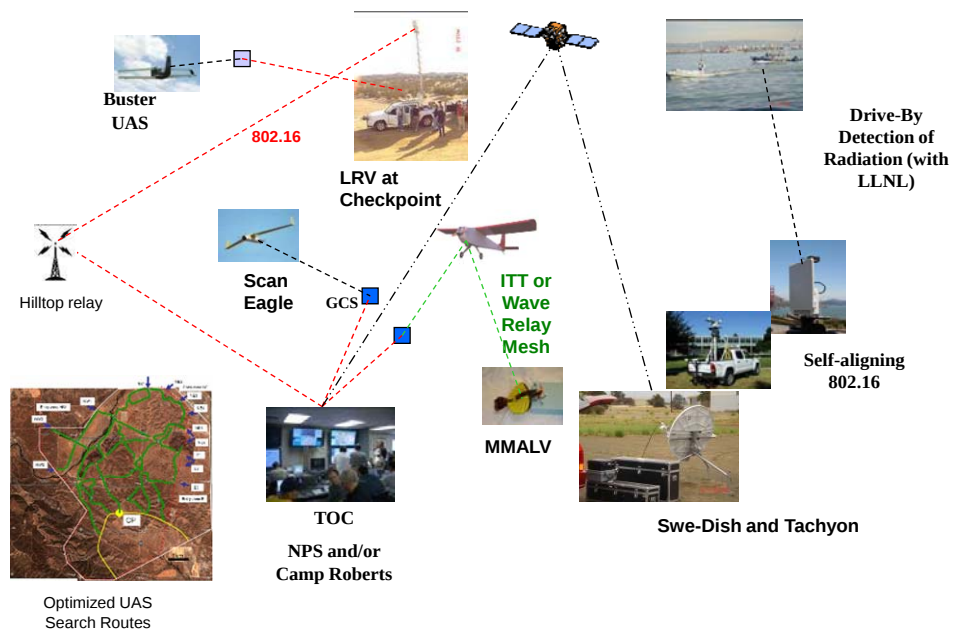


Figure 3. Typical self-forming mobile mesh segments of TNT testbed



Figure 4. Tactical applications enabled by self-forming segments of TNT testbed

collecting nuclear radiation and biometric data (Bordetsky, Dougan, Foo, and Kihlberg, 2006). While this is under somewhat controlled experimental conditions, results even within an order of magnitude of this time allow the boarding party to take action while they are still on board the suspect vessel and long before the suspect can evade. Figure 6 illustrates MIO Testbed in action supporting simultaneous interdiction of target vessels in open waters, inner bay, and riverine and with an immediate reachback to expert sites and multipoint video/data exchange between the boarding parties.

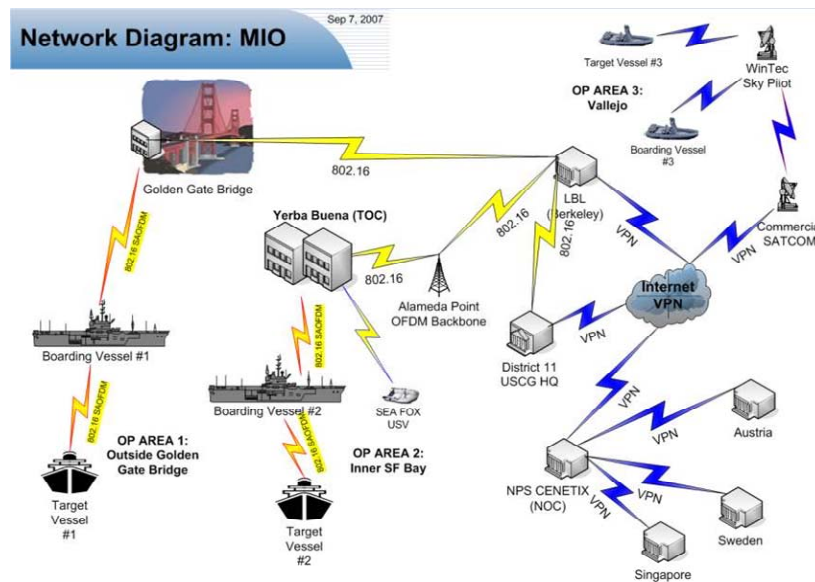


Figure 6. Simultaneous interdiction and data sharing between boarding parties conducted in three geographically distributed locations.

Each MIO experiment appears to be a significant next step forward in evaluating the use of networks, advanced sensors, and collaborative technology for rapid MIO response, including the ability to search for radiation sources, set up ship-to-ship and ship-to-shore communications while maintaining network connectivity with command and control (C2) organizations and collaborating with experts on the radiological and biometrics identification threat.

For example, the specific goal for the MIO 08-4 experiment was to explore new sensor, networking, and situational awareness solutions for interdicting, searching, tagging, and monitoring a large vessel as well as small craft, threatening the security of the coastal metropolitan areas on the scale of the radiological threat in the Port of NY and NJ and subsequent events in the riverine area of Hampton Roads, VA.

The situational awareness focus of the experiment was to explore the requirements for broad interagency collaboration and data sharing using the capabilities

of PANYNJ JSAS, JAC feedback, and two-way data sharing with the Riverine Area of operation.

Figures 7, 8, and 9 illustrate the TNT MIO testbed in action during the MIO 08-4 search of the large cargo vessel in the Port of Newark and high-speed Riverine chase nearby Ft. Eustis.

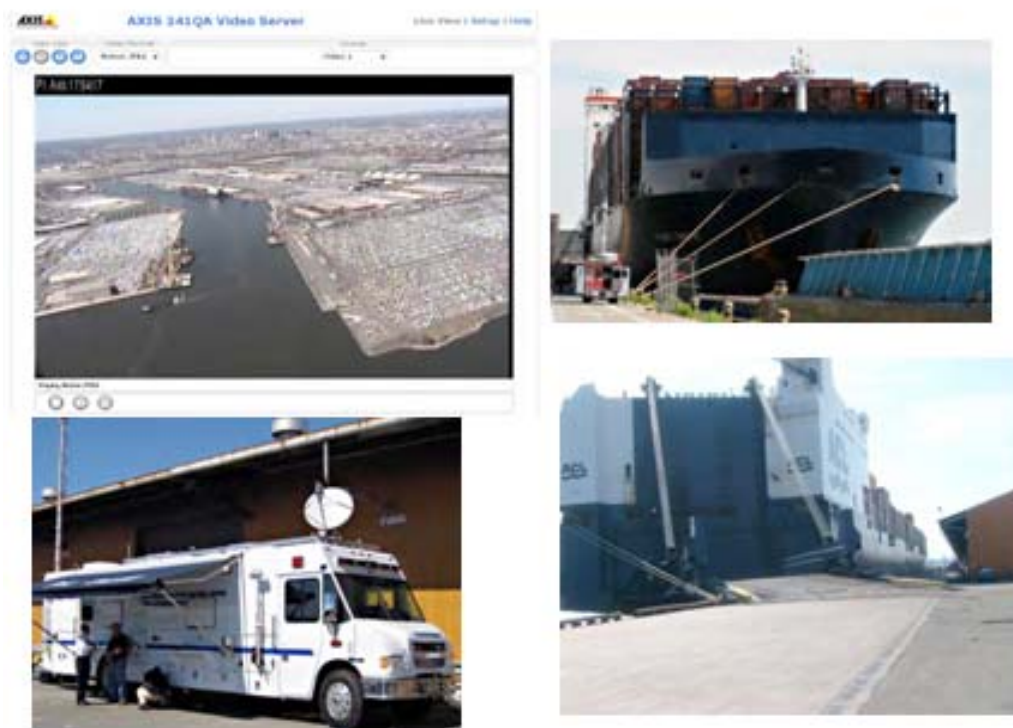


Figure 7. TNT MIO Testbed in action providing on-the-move network to multiple boarding parties searching a large cargo ship and reachback to PANYNJ EOC and DoE expert centers.

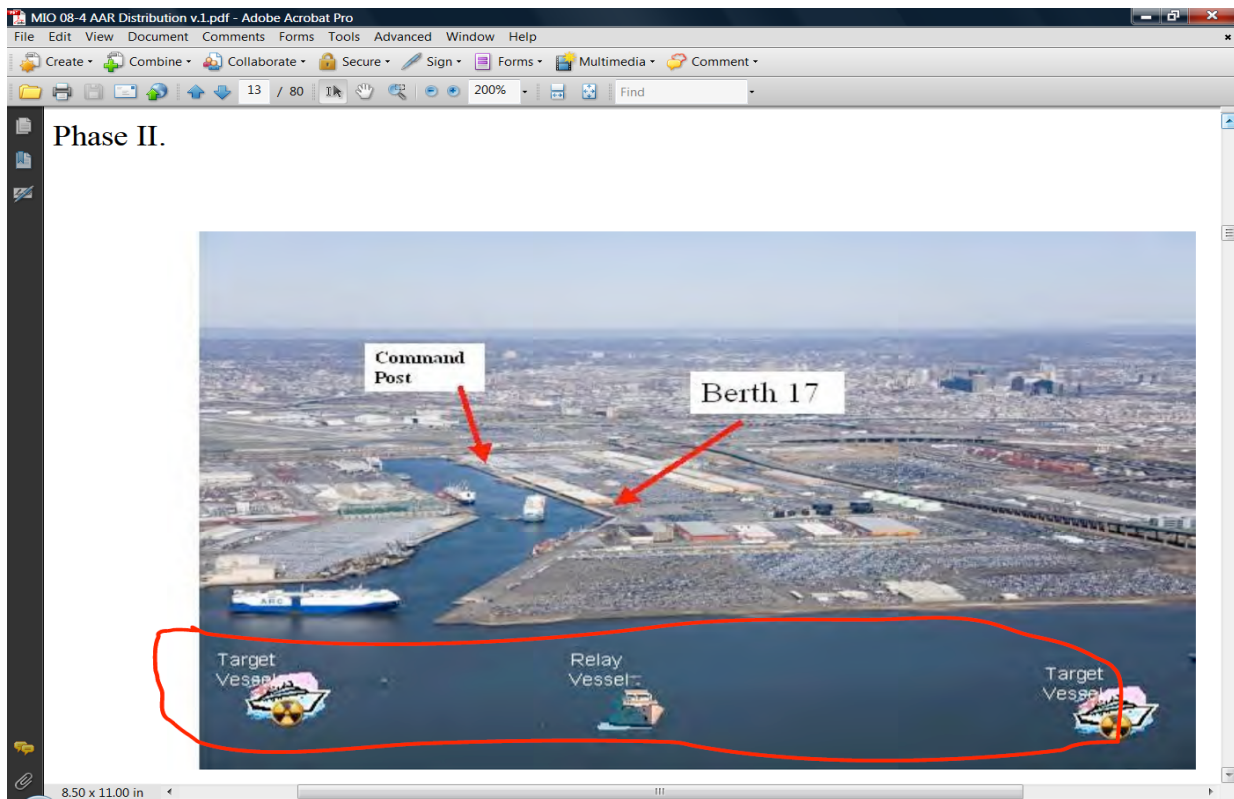


Figure 8. Simultaneous small craft search in Port of Newark, Sweden, and Denmark and data sharing operations.

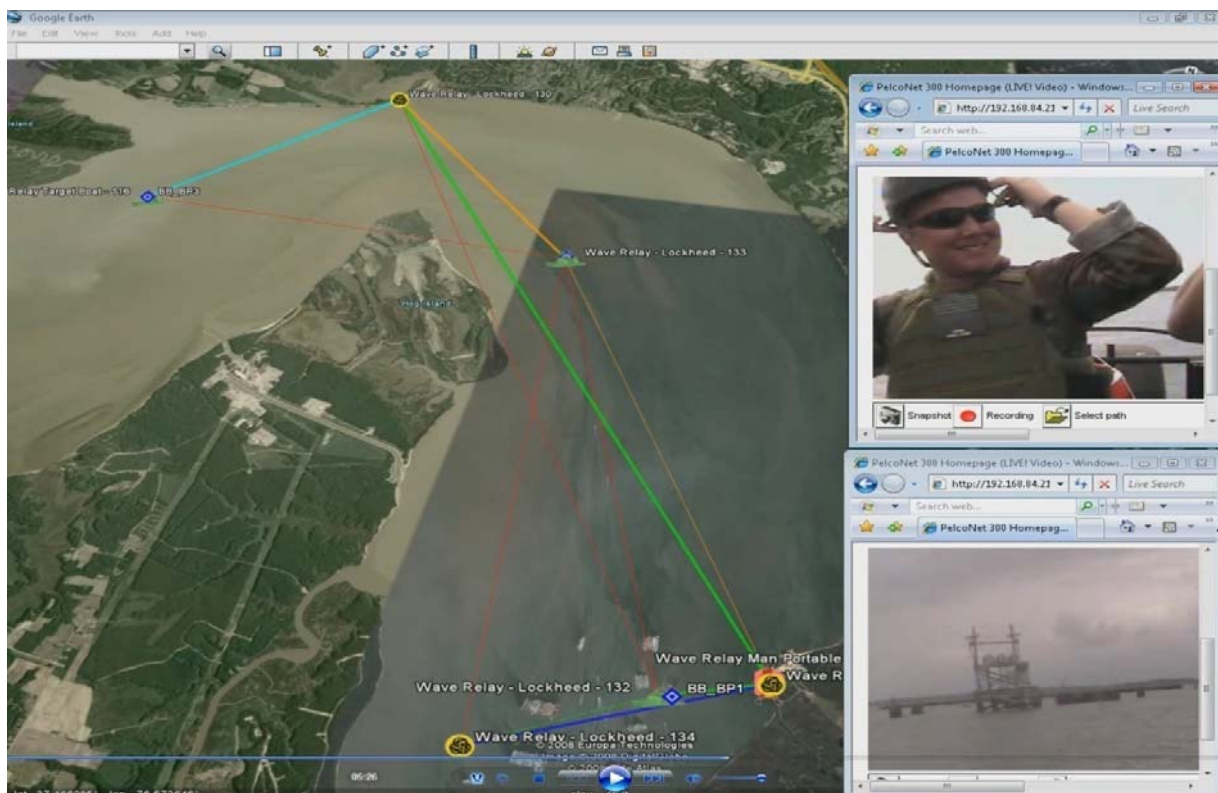


Figure 9. MIO testbed mesh segment in action supporting the video exchange during the high-speed riverine chase of the target vessel.

2. Testbed Service Architecture: An Interface System for Field Experimentation

From the Systems Theory standpoint the TNT testbed represents a unique research service of social and information networking. It provides for the adaptation and integration processes between people, networks, sensors, and unmanned systems. For a few days of intense experimentation the TNT testbed military, academic, and vendor users become a community of **tactizens** engaged in rapid system design processes, which produce new forms of synergy in the TNT cyberspace of man and tactical machinery. The new term of *tactizens* is our reflection on *Second Life* metaphor of *netizens* (Sectcliffe, 2009).

The testbed enables several layers for integrating models, tools, and experimentation procedures:

- The TNT *tactizens* can integrate their sensors and mesh networking elements in the unclassified but closed IP space of the TNT testbed by getting fixed IPv4 and lately IPv6 addresses. Figure 10 illustrates the online portal enabling rapid integration of experimental assets in TNT testbed IP space,
- Users can connect their remote local area network, including command and operation centers, via the virtual private network (VPN) client on top satellite or commercial IP cloud services,
- Sensors and unmanned vehicles can be integrated with the TNT Situational Awareness Environment via the applications layer interoperability interface. The current option includes Cursor-on-Target (CoT) integration channel, initially developed at MITRE (Miller, 2004), comprised of the CoT message router and CoT XML adapters for each node needed to be integrated (Figure 11). In the very near future we will consider adding the Common Alert Protocol (CAP), which is becoming widely used by the DHS community,
- Human operators (both remote and local) can access the testbed collaborative environment via the collaborative portal or peer-to-peer collaborative clients, situational awareness agents, video conferencing room (Fig.12), and video client. This is human layer interface to the testbed.
- At the physical level the testbed reaches to even lower levels (like multiple mesh network enabled unmanned systems) which permit researchers to experiment with such things as airborne sensors and cooperative control (Fig. 13) without having to be concerned about network connectivity.

By accessing testbed at different levels, varying from application to physical, the TNT testbed users could have unique capability of exploring possible adaption patterns, i.e. management of their resources by experimenting with applications load or physically moving and re-aligning their assets. Figure 14 represents the TNT testbed adaptive management interface.



Figure 10. Plugging IP assets in the TNT Testbed: IP Space Portal (Designed by Eugene Bourakov)

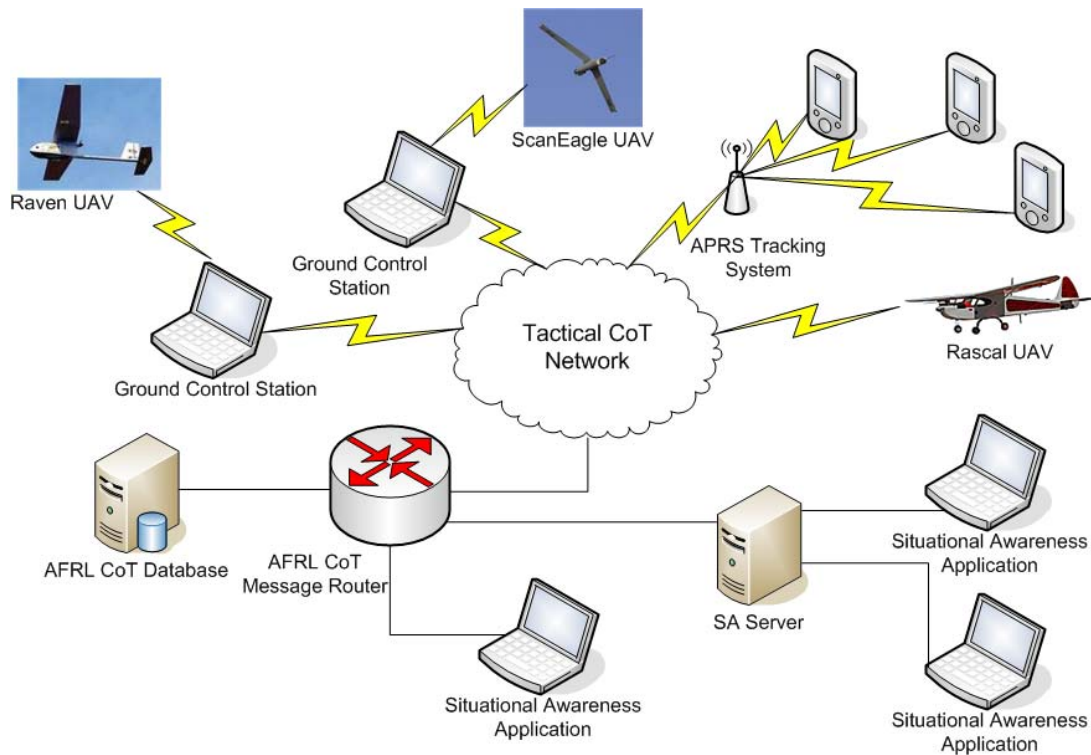


Figure 11. Applications Layer Testbed Interface via the CoT channel (Diagram provided by Michael Clement)

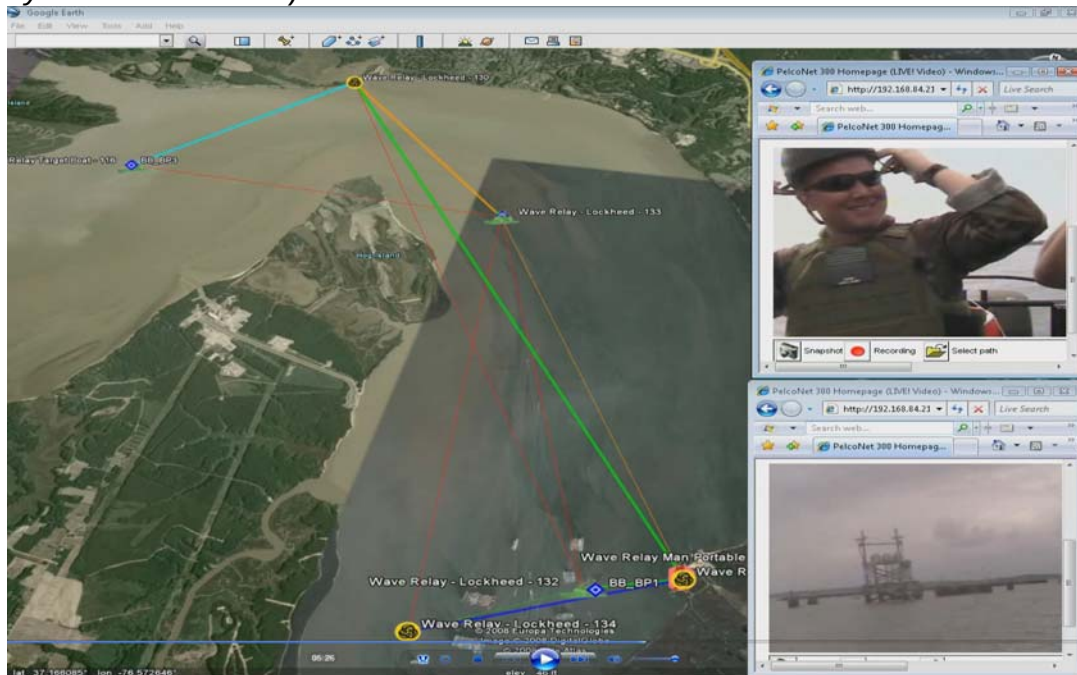


Figure 12. Operator interface: video clients and SA View in the Riverine Operations

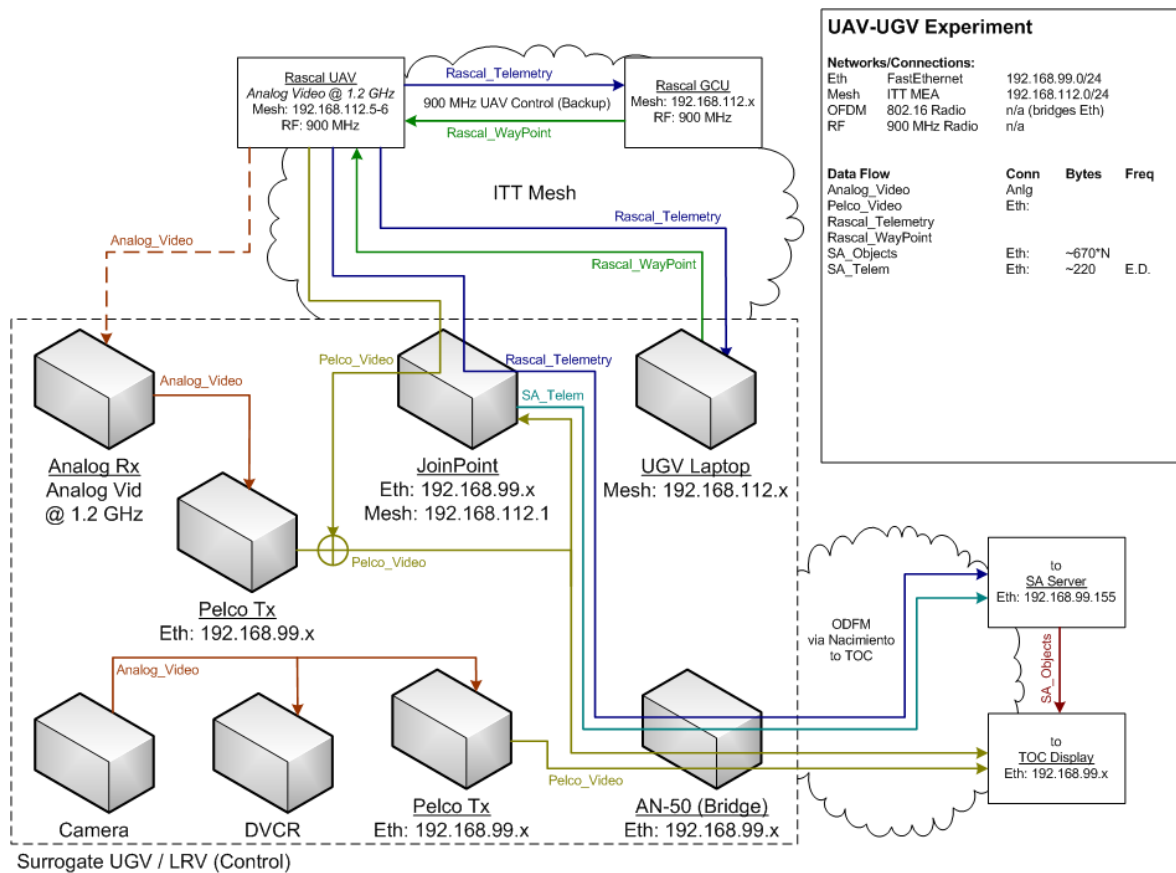


Figure 13. Mesh network interface enabling cooperative control of UAV and UGV
(Diagram provided by Michael Clement)

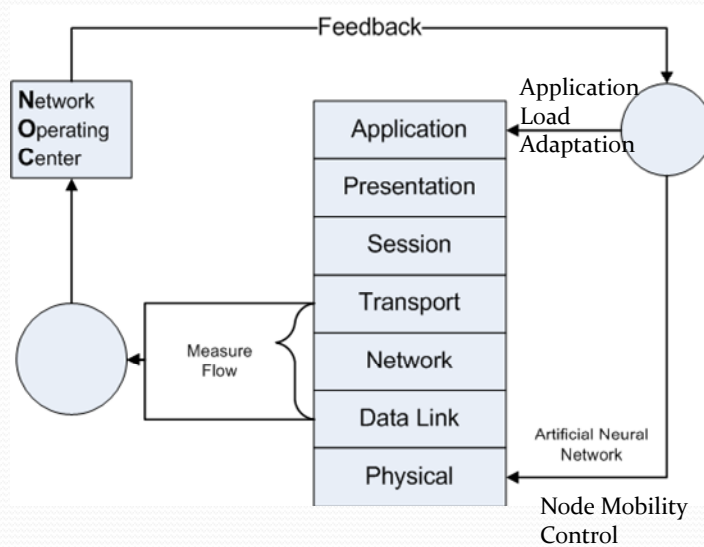


Figure 14. Layers of Adaptation in TNT Testbed

3. Field Model for Exploring Tactical Networking and Collaboration Frontier

From the scholarly stand point the TNT testbed represents a unique field model of emerging complex relationships between man and machine in the tactical networking and collaboration frontier. Exploring feasibility and major operational constraints associated with those relationships allows the TNT experimentation team to identify critical elements of tactical networking and collaboration frontier. Tables 1 and 2 illustrate several examples of these findings.

Table 1. Shaping Tactical Networking Frontier

	Self-forming agile adaptive networks	Unmanned systems-sensor-decision maker cooperative networks:	Through-the-wall N-LOS Networking
Self-Organizing Mesh Wireless Networks	TNT Reports from 2005-2008		
Network and SA controlled UAVs, USVs, UGVs: Unmanned vehicle is controlled by submitting the way points via tactical N-LOS mesh network		An ongoing study with Bourakov, Clement, Jones, Dobrokhodov, Kaminer (Clement, et.al., 2009) and (Jones, et. Al., 2009)	
Network-on-Target: Peer-to-peer links configured from the top of Common Operational Picture interface, self-aligning directional antennas	(Bordetsky & Bourakov,2006)		
Hyper-Nodes with 8th Layer: Tactical Self-Forming nodes as miniature network operations centers	(Bordetsky & Hayes-Roth, 2007)		
DMs as sensors to unmanned systems: Operators decision space MIB available to the unmanned system agents	First results accomplished in the thesis project of LCDR James Gateau, (Gateau &Bordetsky, 2008)		
Networking-by-touch: transmitting data via highly adaptive human network by using physical or electronic touch	First results accomplished in thesis of Rideout & Strickland (NPS), continuing research with Bourakov (NPS) Elman (MIT), and Lindeman (WPI): (Rideout and		

	Strickland, 2007), (TNT 08-2 QLR), (TNT 08-4 QLR)		
GPS denial navigation		An ongoing study since 2007 with Bourakov and MIT team (TNT 07-4 QLR, 2007), (TNT 08-2,QLR 2008)	
Ultra Wideband (UWB) Mesh networking: Integrating the UWB link into the peer-to-peer wireless mesh network			An ongoing study with Bourakov (NPS), Win and Weymereesh (MIT) (TNT 08-4 QLR 2008)
Projectile-based Networking		TNT MIO 07-4 After Action Report, 2007	
Small Distributed Unit Private Tactical Satellite Network	Study started in 2007, first results accomplished in thesis project of MAJ Conrad and LCDR Tzanos (Conrad and Tzanos, 2008)		
Small Distributed Unit Private Tactical Cellular Network		Study with Bourakov started in 2008 (TNT 08-4 QLR, 2008)	

Table 2: Shaping Collaboration Frontier:

	Collaborative networks for rapid interagency data sharing and expert response	Synergy of social and information networking
MIO Collaboration: Bringing the remote expert advice to an immediate support of the boarding officers	An ongoing research with Dougan & Dunlop (LLNL), Bourakov, Hutchins, Looney, Clement , Vega , Hudgens, Bergin-NPS; Friman (Swedish Defence Research Agency), Pickl (University of Bundeswehr)): (Bordetsky et al, 2006), (Hutchins, et.al., 2006), (Bordetsky & Friman, 2007), (Bordetsky & Hutchins, 2008),	With Hudgens, Vega, Koons, Bergin, Bekatoros: (Hudgens and Bordetsky, 2008), (TNT MIO 08-4 Report)
SA and Collaborative platforms interoperability: Propagating alerts between NPS SA tools, Port Authority NY-NJ (PANYNJ) Joint Situational Awareness System (JSAS)	First results accomplished with Bourakov and Clement (NPS), Reimers (BAE), Poulsen and Cooper (PANYNJ), Lindt (Kokums, Sweden), Hoy-Petersen and Nielsen (Systematik, Denmark): (TNT MIO 08-2 Report, 2008), (TNT MIO 08-4, Report, 2008)	
Collaboration with Coalitions partners		SNWC BFT-NPS SA-JSAS (with Hansson & Lindt (Sweden) - Danish MBS-NPS SA-JSAS (with Hoy-Petersen, Nielsen, and Riderring-Systematik, Denmark)

4. Conclusion: Enabling Business Process of Synergy Development

On top the TNT testbed interfaces there is unique business process, which allows participants to explore synergy of their solution. Quarterly experiments, supported by student and faculty experimentation services, allow the *tactizens* (vendors, academic, and other government partners) to rapidly adapt their solutions to the TNT environment and provide a unique collaborative environment in which the innovation of participants often results in additional unscheduled experimentation using combined technologies. The shortest adaptation cycle is 3-4 days of rapid team design during the TNT experiment. The next level cycle includes 8-10 weeks of research projects delivering feasibility or constraints analysis experiments. The

longer adaptation term is in conjunction with dedicated student thesis project (about 6 months).

Industrial Participation		
Adaptive Flight	I-C Mobilisa	Remote Reality
AGI	iGov Technnologies	Restech
Amrel	ImSAR	Retica
AOptix	IST-Textron	Sarnoff
Applied Signal Technology	L-3 Com	Space Data Corp.
BAE Systems	LMCO	Step Labs
Blackbird Technologies	McLane Adv. Technologies	Strategic Initiatives
CDI	Metson Marine	Swe-Dish
CHI	Mission Technologies	Toyon Research
Commsfirst	Mitre	Trident Tech. Solutions
CrossMatch	Networx	TrellisWare
DRS	NGC	Triggerfinger
ESRI	Orion Networking	WinTech Arrowmaker
Extreme Endeavors	P&LE	XTAR
General Dynamics	Persistent Systems	
Harris RF Comms	Procerus	
Honeywell	QinetiQ	
Hoyos	Redline Communications	

Figure 15. TNT Testbed Industrial Users in 2008 Exepriments

To the business community supporting the experiments (Figure 15), the TNT testbed with it's research services and interfaces, which enable discovery and constraints analysis for frequently immature and disintegrated prototypes, provides a unique incubation path to the market of emerging tactical operations.

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**Center for Network Innovation and Experimentation
USSOCOM-NPS Experimentation Cooperative
Naval Postgraduate School, Monterey CA**

**14-th ICCRTS, C2 and Agility
Washington DC, Wednesday, June 17-th 2009**

Motivation

- Beginning in 2002, a team of Naval Postgraduate School researchers together with sponsors from USSOCOM, and later joined by the OSD and DHS S&T Programs, started a new campaign of discovery and constraints analysis experiments (Alberts and Hayes, 2007), which is now collectively known as Tactical Network Topology (TNT) Experiments.
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- The second direction involves Maritime Interdiction Operation (MIO) experiments with Lawrence Livermore National Laboratory, USCG, First Responders (San Francisco Bay, New York/New Jersey) supported by HLD and HLS S&T Programs and DoE agencies. These experiments are conducted twice a year and are also supported by the overseas partners from Sweden, Germany, Denmark, and Singapore.

Outline

- Tactical Networking Testbed: Man-Machine Plug-and-Play Systems Enabling Sustainable Experimentation
- TNT Tactizens: An Experimentation Community led by NPS, SOCOM, LLNL, supported by DoD, DHS, DoE, academic, local governments, corporate, and foreign partners
- Plug-and-Play ISR/HVT Testbed with Global Reachback: Camp Roberts segment with reachback to East Coast Centers
- Plug-and-Play TNT MIO Testbed Segment: SF Bay, East Coast and Overseas
- Testbed Service Architecture: An Interface System for Field Experimentation
- Field Model for Exploring Tactical Networking and Collaboration Frontier
- Conclusion: Enabling Business Process of Synergy Development



USSOCOM – NPS Field Experimentation Cooperative: TNT Testbed Community of Tactizens



Large Interdisciplinary NPS Team

FY08: 27 Thesis Students

31 Faculty

Includes 21 PhD, 4 PhD Students

Course Projects: IS, OR, DA, MET

9 Departments and Institutes

Programs Utilizing TNT Testbed

DARPA HURT ACTD

DARPA MAV ACTD

USSOCOM Global Reach ACTD

AFRL JASMAD

MCWL Distributed Operations

OSD/HD MDA

Participating Universities

Virginia Tech	Case
University of Florida	MIIS
WVUF	NDU
Nat. Univ. Singapore/DSTA	MIT
Swedish Naval Warfare Ctr	
Univ. of Bundeswehr	Salzburg Research

Foreign Country Participation in MIO

Austria	Germany	Singapore	Sweden
Australia (08)	Canada (08)	Denmark (08)	UK (08)

Broad DoD and Gov't. Participation and Support

- USSOCOM
- USASOC
- AFSOC
- NAVSOC
- JSOC

Participating DoD and U.S. Gov't.

AFRL	BFC
DARPA	DTRA
LLNL	MARAD
NSA NTIO	NRL
ONR	ONR 113
SPAWAR	USCG/D-11
ARL	OSD/HD
OSD-RRTO	STL
USASMDC	JHU APL
USMC-MCTSSA	NIST
NSWC-Dahlgren	NAWC- CL
TSWG	

Industrial Support

WinTec	Orion Networking
AGI	CHI Systems
Inter-4/SNC	Orion Networking
Redline Communications	Trident Systems
Lockheed Martin	Cross Match
Mission Technologies	Retica
Honeywell	XTAR
Mitre	DRS
Space Data Corporation	Procerus
AOptix	CDI
Chang Industries	L-3 Comm
SCAN Pacific Northwest	Insitu
General Dynamics	

State and Local Government

Alameda County Sheriff's Office
Oakland Police Dept.
San Francisco Police Dept.
NY-NJ Port Authority Emer. Off.
Calif. Office of Emerg. Services
U.S. Park Police

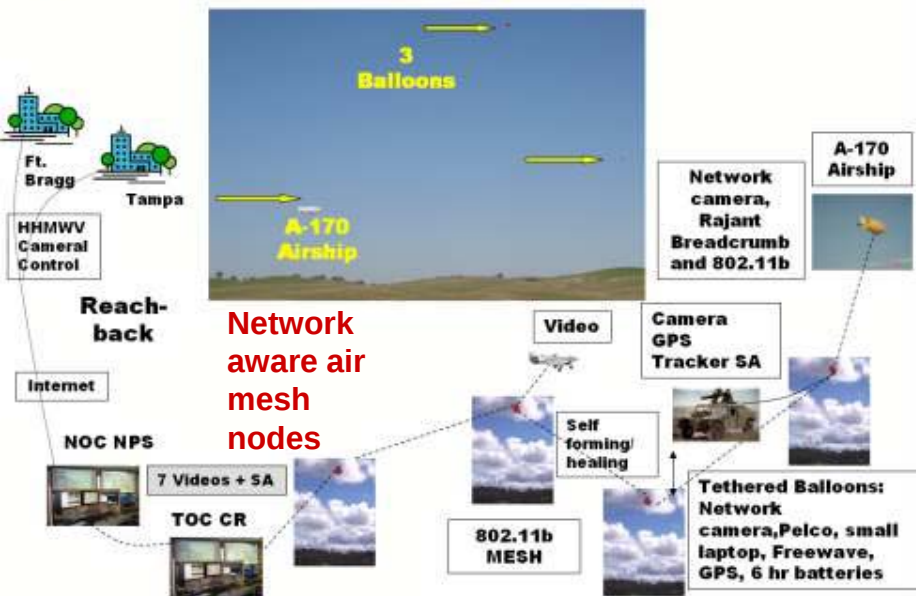
National Guard

West Virginia – Camp Dawson
Indiana – Camp Atterbury
California (08)



TNT 05-1, Nov 2004

MESH Topology



TNT 05-2 Feb 05

Improved Camp Roberts TOC



VC-6 with TERN UAVs



TERN Network Payload

Cypress Sea Approaching USCGC HAWKSBILL - Radiation Detection



Balloon Payload

Surrogate Light Reconnaissance Vehicle



NA Sea Nodes

TNT 05-2 Feb 05

Cypress Sea Support Boat



Resolution Target for EO Performance Prediction



Cypress Sea NOC



SA for Cypress Sea, Pelican, Pelican Video



NAVBOARD

Pelican 802.16/ OFDM Payload



ARIES AUV



TNT 05-2 Feb 05

Above and Below Water Situational Awareness for Combat Diver

NPS NOC



802.16/OFDM VoIP



Surrogate UAV



GPS

NA enables seamless SA



Shore Image



ARIES AUV

802.11b or Mesh

Cypress Sea with SA



Mine Location and Image

NAVBOARD



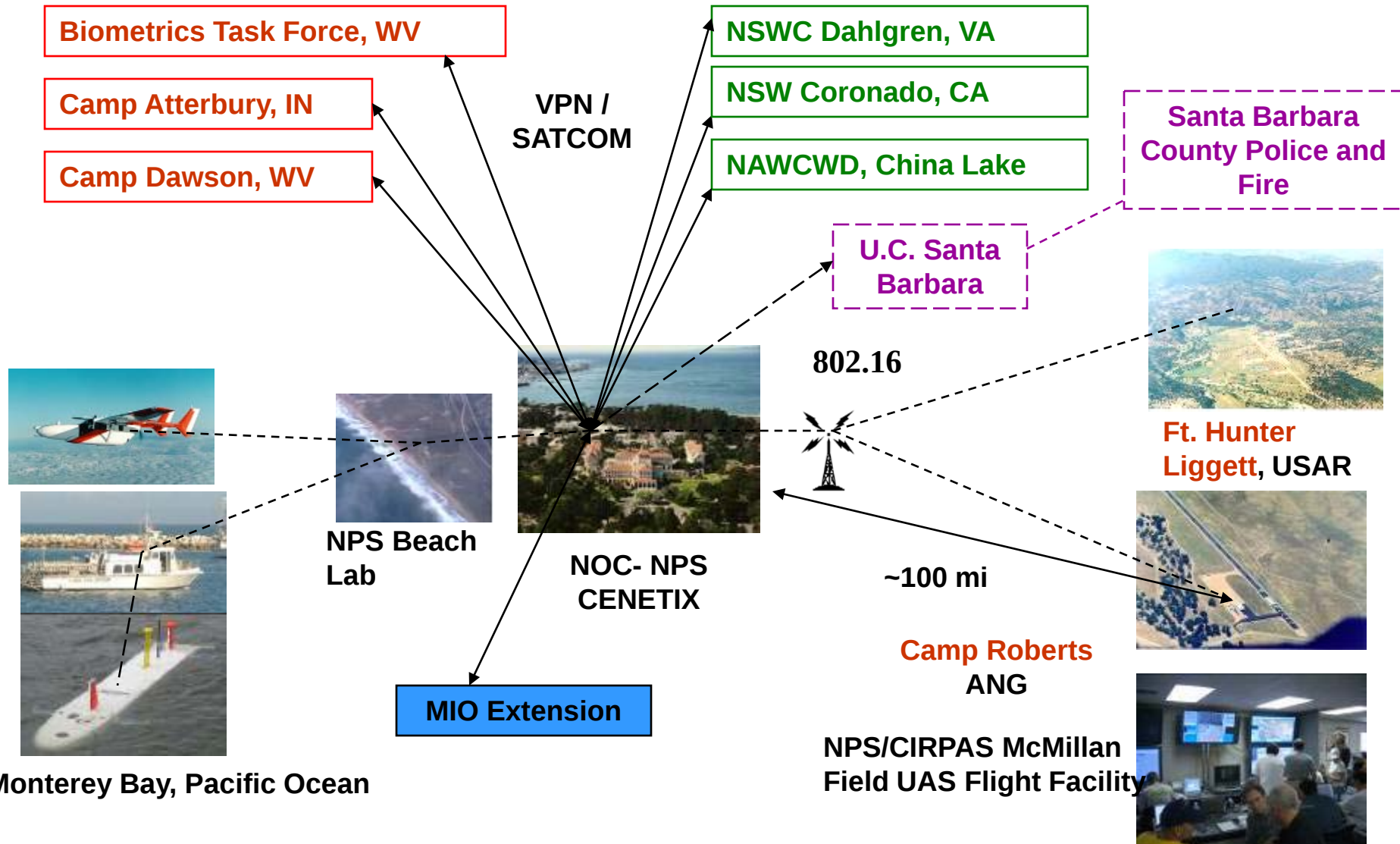


TNT Testbed: Plug-and-Play Interface System for Field Experimentation

- TNT testbed represents a unique research service of social and information networking.
- Testbed provides for the adaptation and integration processes between people, networks, sensors, and unmanned systems.
- For a few days of intense experimentation the TNT testbed military, academic, and vendor users become a community of *tactizens* engaged in rapid **system design processes**, which produce new forms of synergy in the TNT cyberspace of man and tactical machinery.
- The new term of *tactizens* is our reflection on *Second Life* metaphor of *netizens* (Sectliffe, 2009).

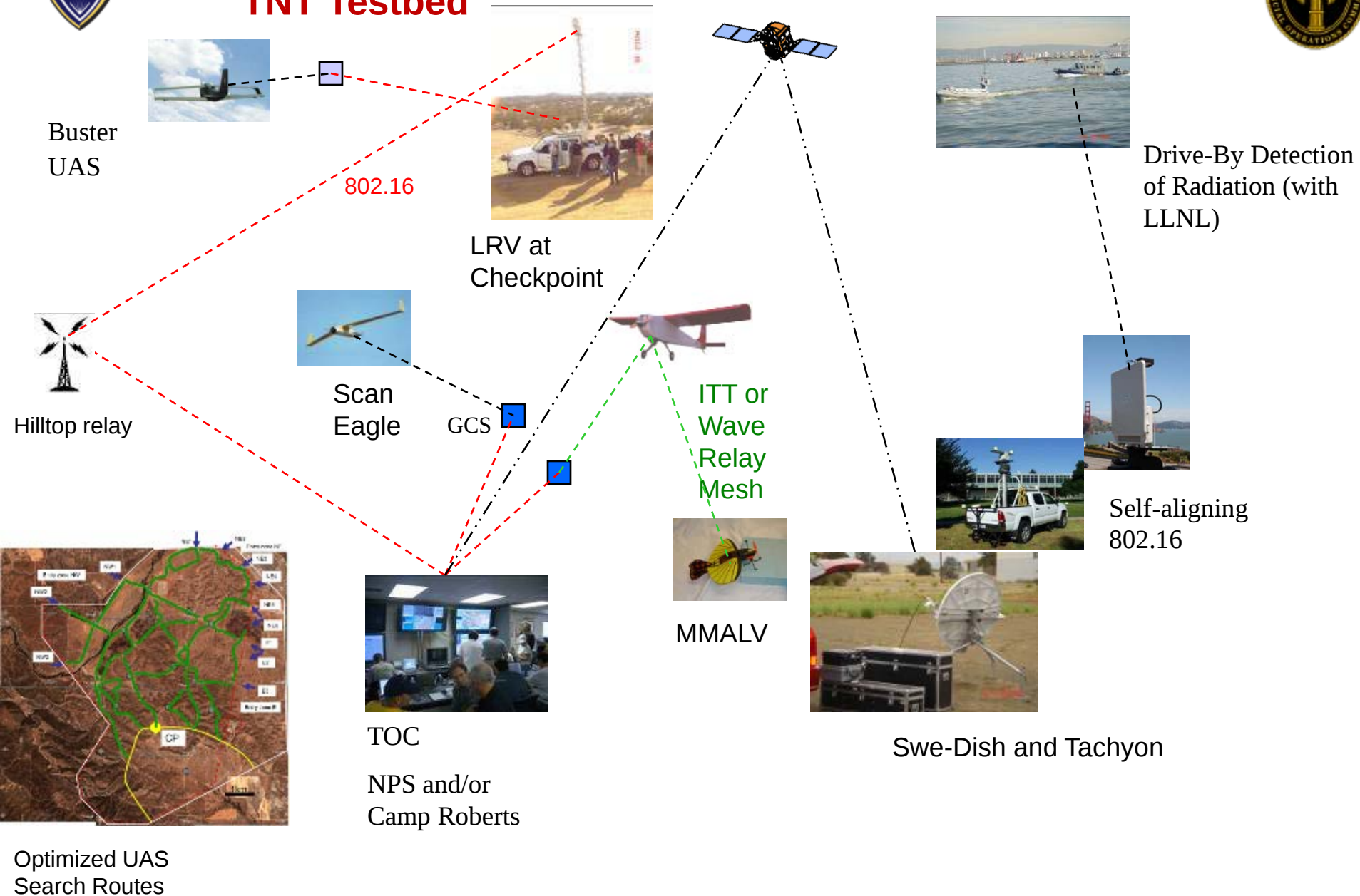


ISR/HVT Operations Segment





Typical Self-Forming Mobile Mesh Segments of TNT Testbed





Examples of New Tactical Applications Enabled by TNT Testbed



JHU/APL Fully Autonomous UAS Swarm for Cooperative Search and Tracking



USMC Distributed Operations – Rapid Network Deployment



Light Reconnaissance Vehicle/Mobile TOC at Checkpoint with Biometrics



Individual Identity Friend or Foe Patch



Rapid Biometrics ID: Facial Image Check



UAV-Enhanced Battlefield Medical SA and Tactical Networking – TOC

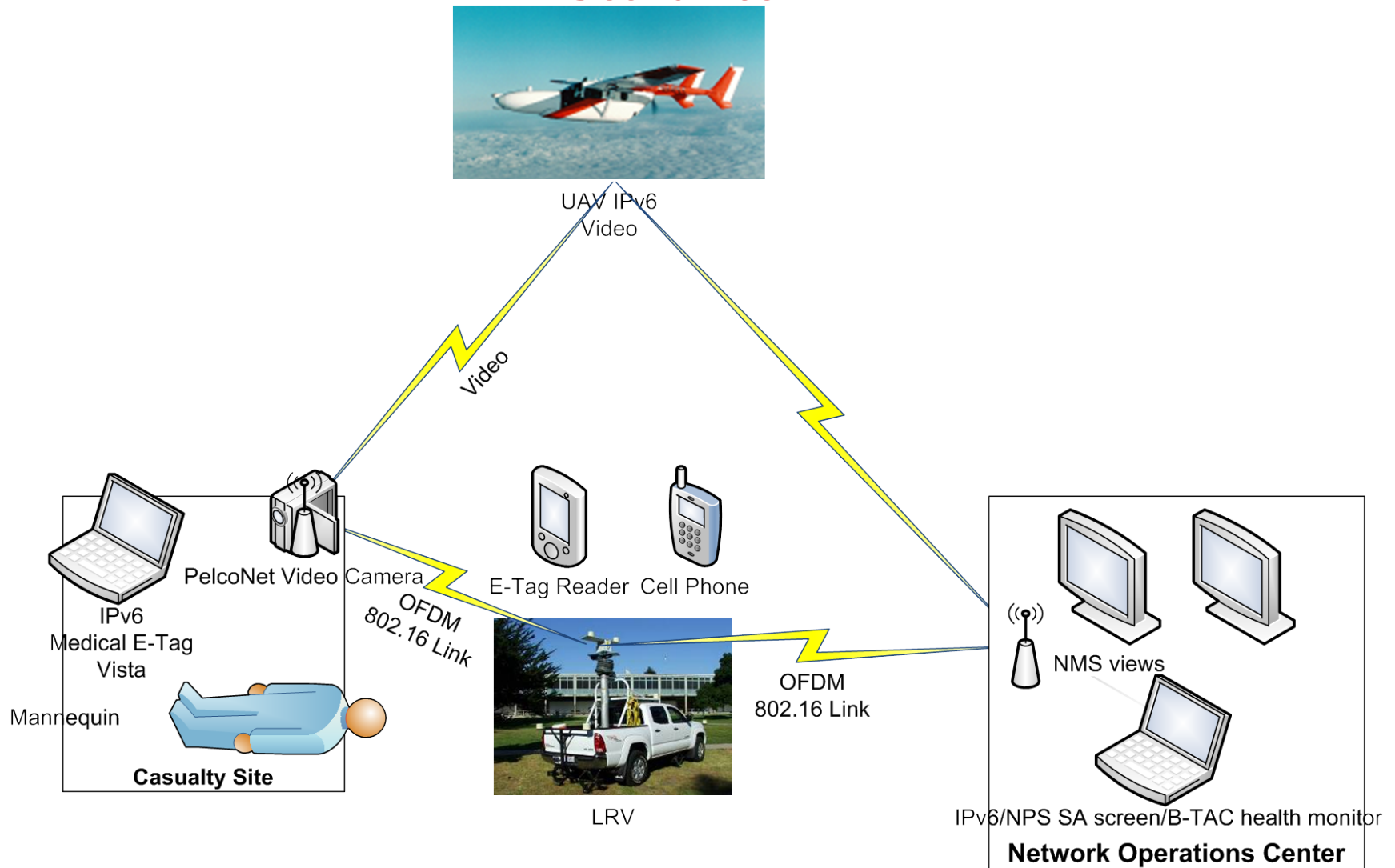


Aerial Search Optimization Model - SA Blue Force Tracking and Satellite Tool Kit for UAV Coverage

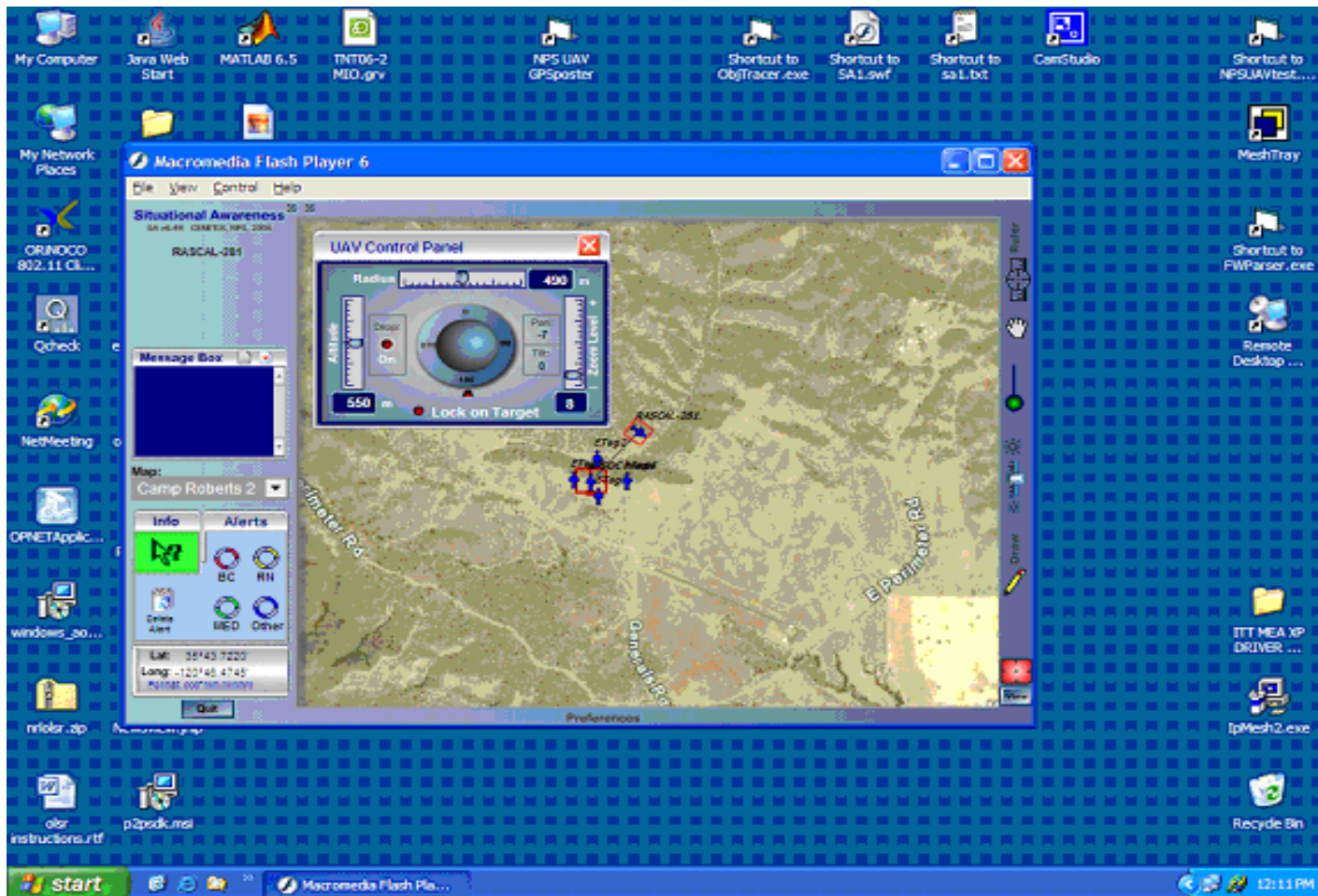
UNCLASSIFIED



UAV and Nano Sensor Augmented Battlefield Medical Scenarios



Battlefield Medical Networking: Medical Commander is flying UAV via the SA interface and wireless mesh. Target is casualty. UAV drops-off blood stopping medication (with E. Bourakov)





PelcoNet 300 Homepage (Server Push) - Micros...

File Edit View Favorites Tools Help

Back Forward Stop Reload Search

Address <http://192.168.99.217/pushed.htm> Go Links

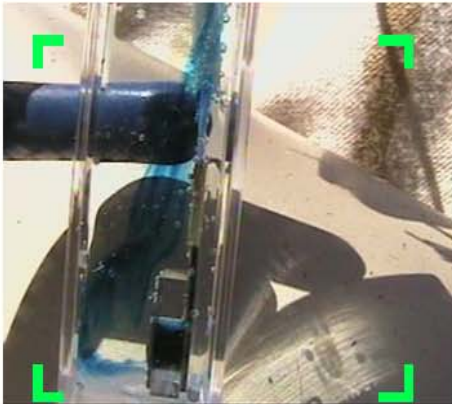
PelcoNet

PELCO VIDEO TECHNOLOGIES FOR DIGITAL NETWORKS

Video 1 Video 2 Server Push Control Setup

Server Pushed Video

352x288



Applet started Internet

My Computer
My Network Places
Internet Explorer
Administrative Tools
Command Prompt
Notepad
Windows Firewall
TNT 08-4 BF Med Screen...
WRL250A... WRL0070...

Sony Network Camera SNE-1229 - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Reload Search Favorites

Address <http://192.168.99.212/en/AViewer.html> Go Links

Setting Home Player

2004-01-01 Thu 18:19:14

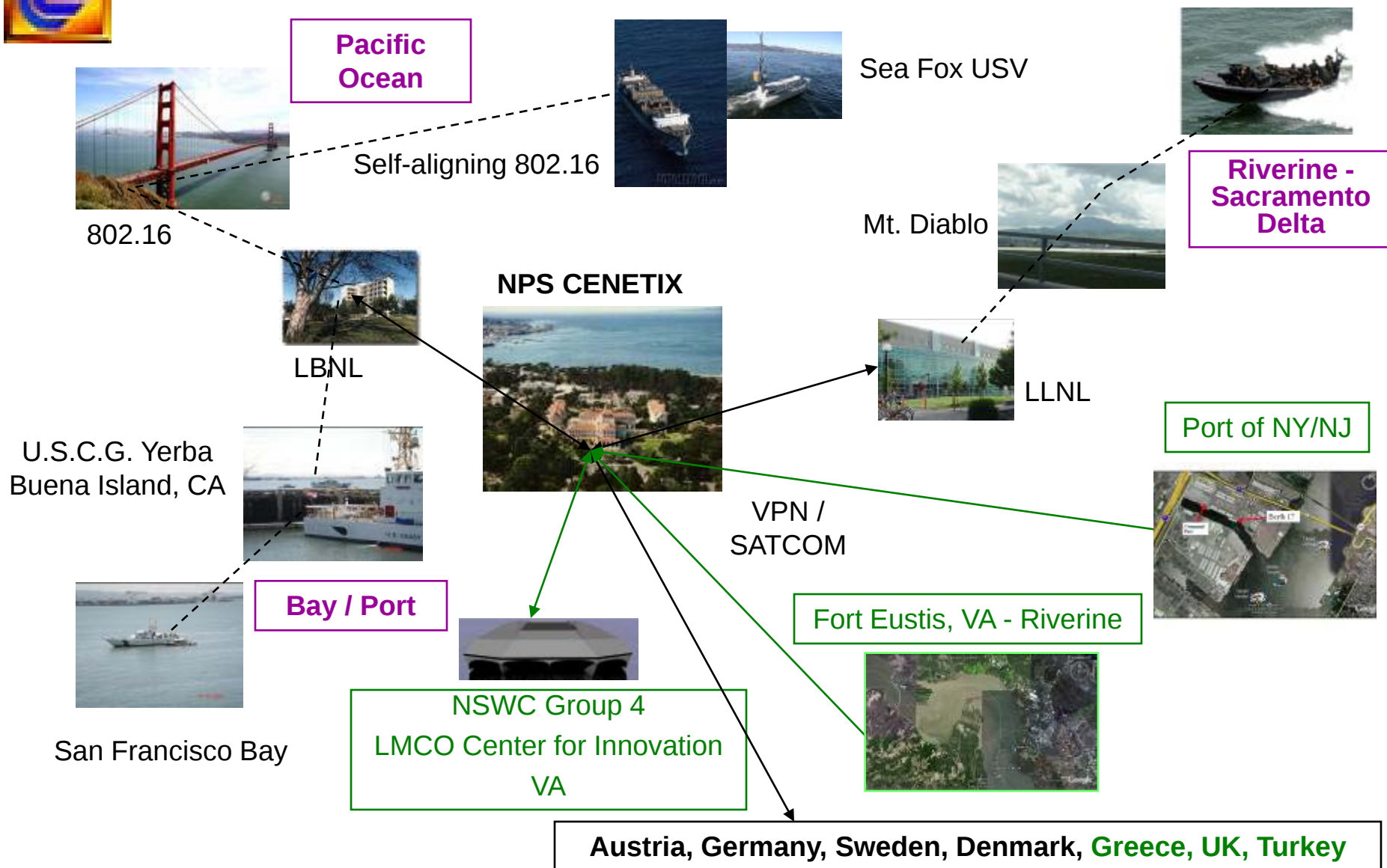


Internet

CamStudio



MIO Testbed Segment: SF Bay, East Coast and Overseas





MIO Tactizens

NPS Team

Networks: ship-to-ship, ship-to-shore
Collaborative Technology
Operations & Command Center
VPN reachback
Unmanned vehicles
Biometrics

LLNL Team

HOPS
Export Control
Radiation Reachback
Plume Modeling
Radiation Sources
Radiation Detection
Ultra-wide band Communication
Explosives Detection

Participating DoD and U.S. Gov't.:

- USSOCOM
- OSD/HD
- Biometric Fusion Center
- NIST
- MARAD
- USCG/D-11
- US Marine Corps
- DOE Radiological Assistance Program
- OFT
- DTRA

Foreign Partners:

National University of
Singapore/DSTA
Swedish National
Defense College/Swedish
Naval Warfare Center
Salzburg Research
University of
Bundeswehr at Munich

State and Local Government

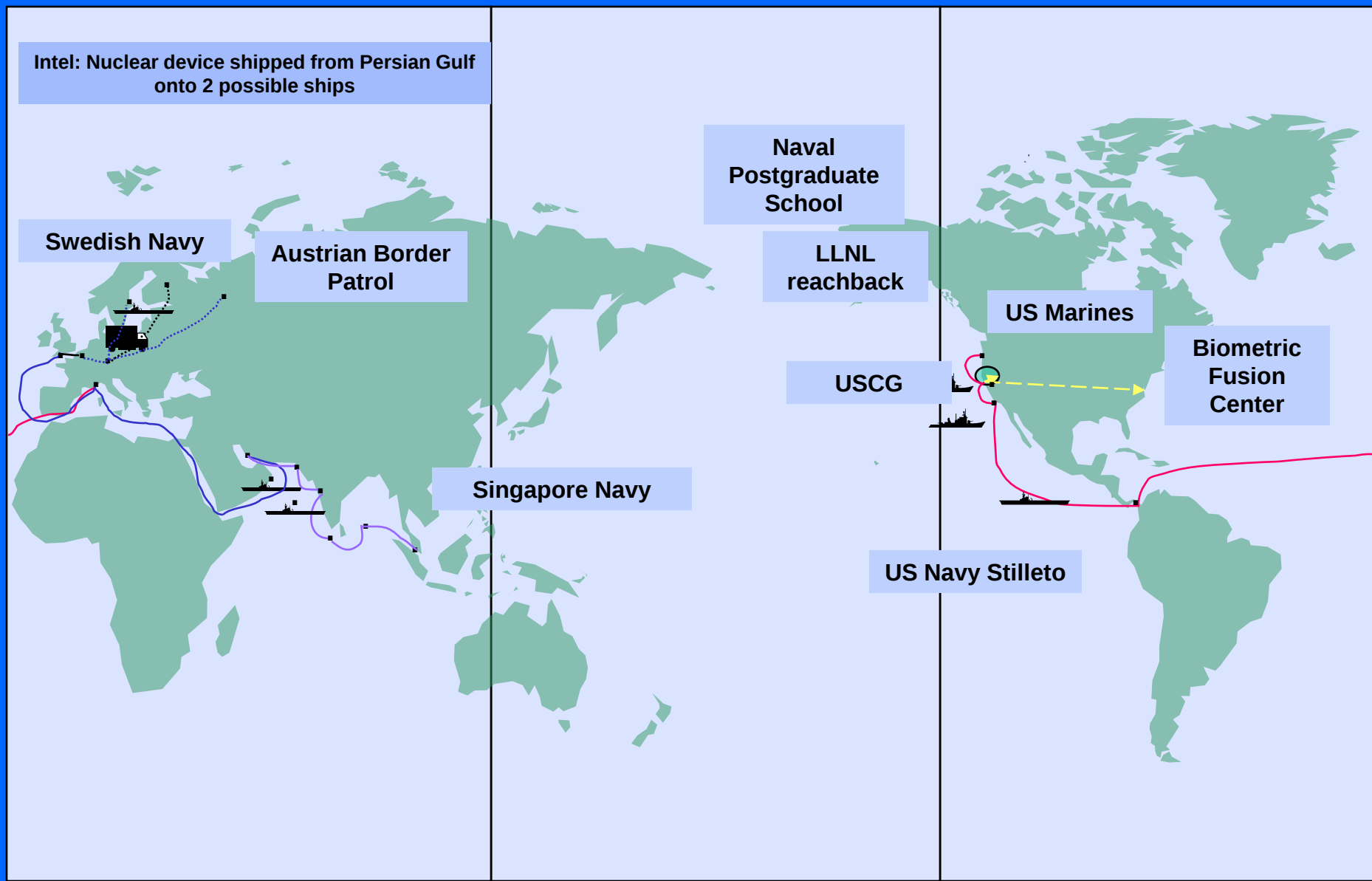
Alameda County Sheriff
Oakland Police Dept.
San Francisco Police
Dept.
California Office of
Emergency Services



Functional Focus of the MIO Testbed Geographically Distributed Teams

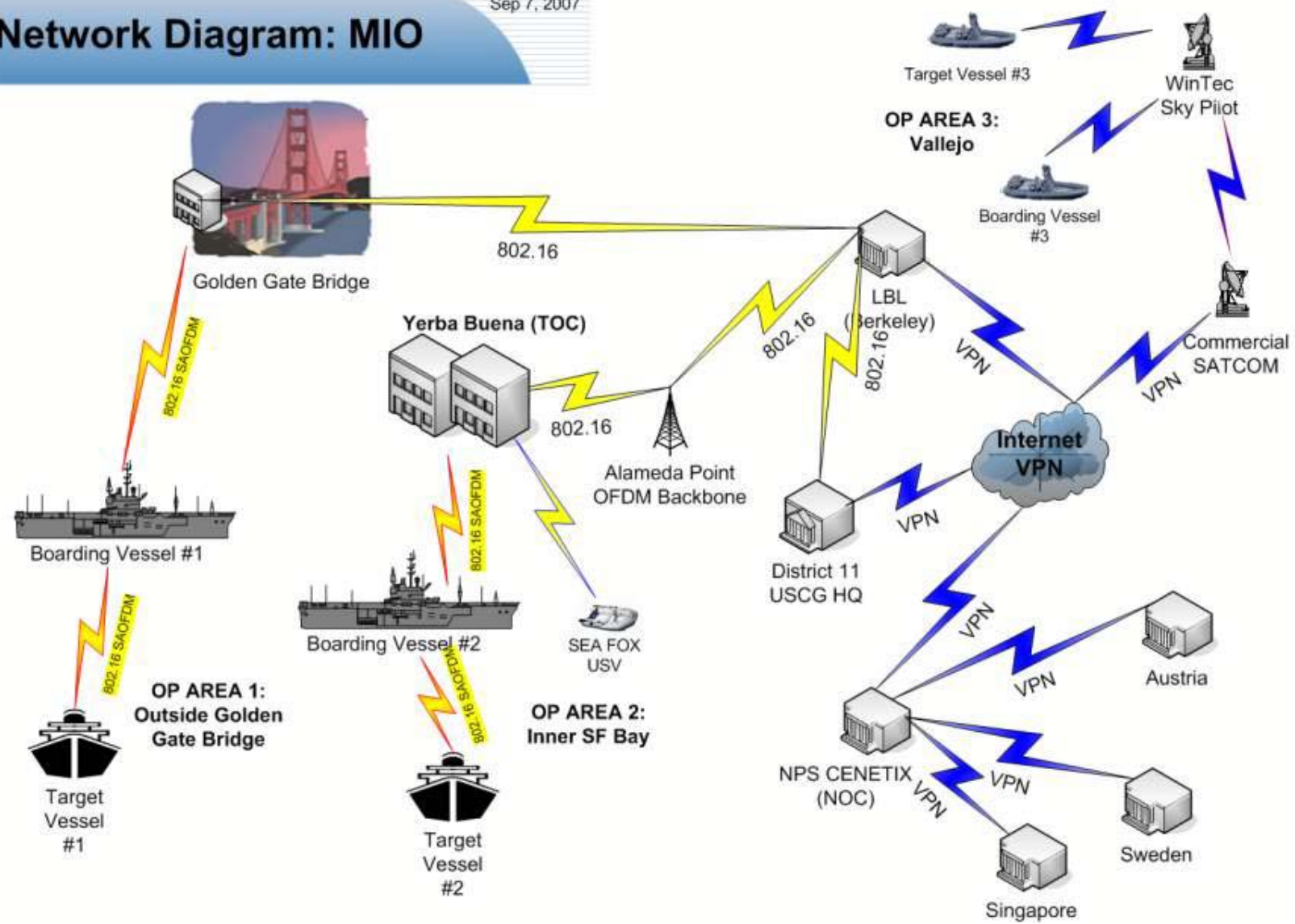
- **San Francisco:** *All new sensor, unmanned systems, and networking technology; data sharing and collaboration with USCG and marine police units, multiple small boat interdiction, DoE reachback*
- **Ft. Eustis:** *Riverine operations, data sharing and collaboration with NSW, USSOCOM, Army Divers*
- **PANYNJ:** *Data sharing and collaboration with NY-NJ area Police and FD first responders, interoperability with DHS JSAS*
- **Swedish NWC:** *Wearable sensor and USV swarm, interoperability with BFT*
- **Danish Naval Systematic Center:** *Diver detection in the Port security area, interoperability with NATO Maritime Boarding Systems*
- **University of Bundeswehr:** *Check points in the smuggling routes, tagging and monitoring*
- **NATO MIO TC in Crete:** *Expert Center for Small Boat interdictions in Mediterranean and Black Sea*

Example Scenario and Global Partners



Sep 7, 2007

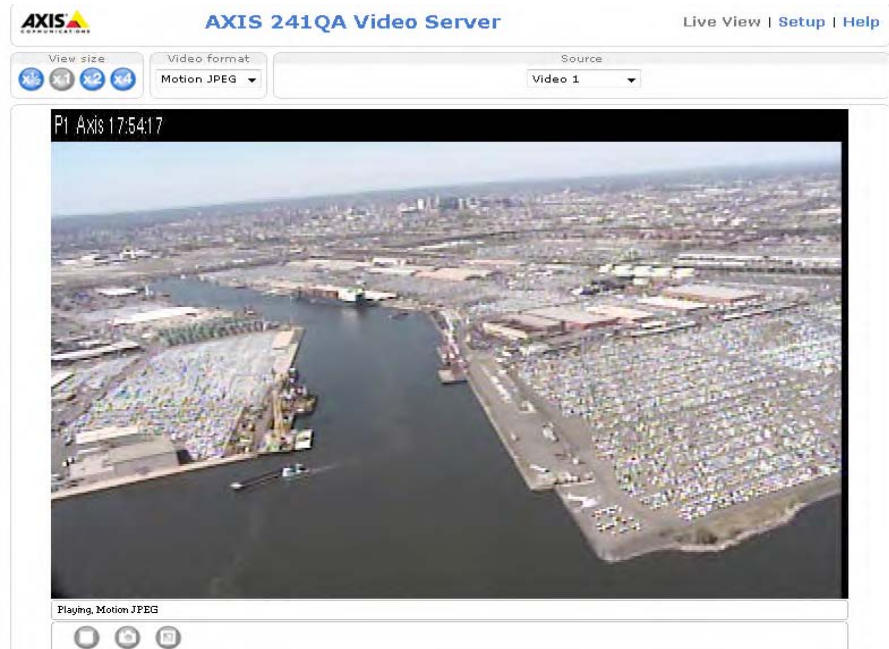
Network Diagram: MIO



Three Boarding Parties simultaneously conducted in the open waters, inner bay, and the Riverine area

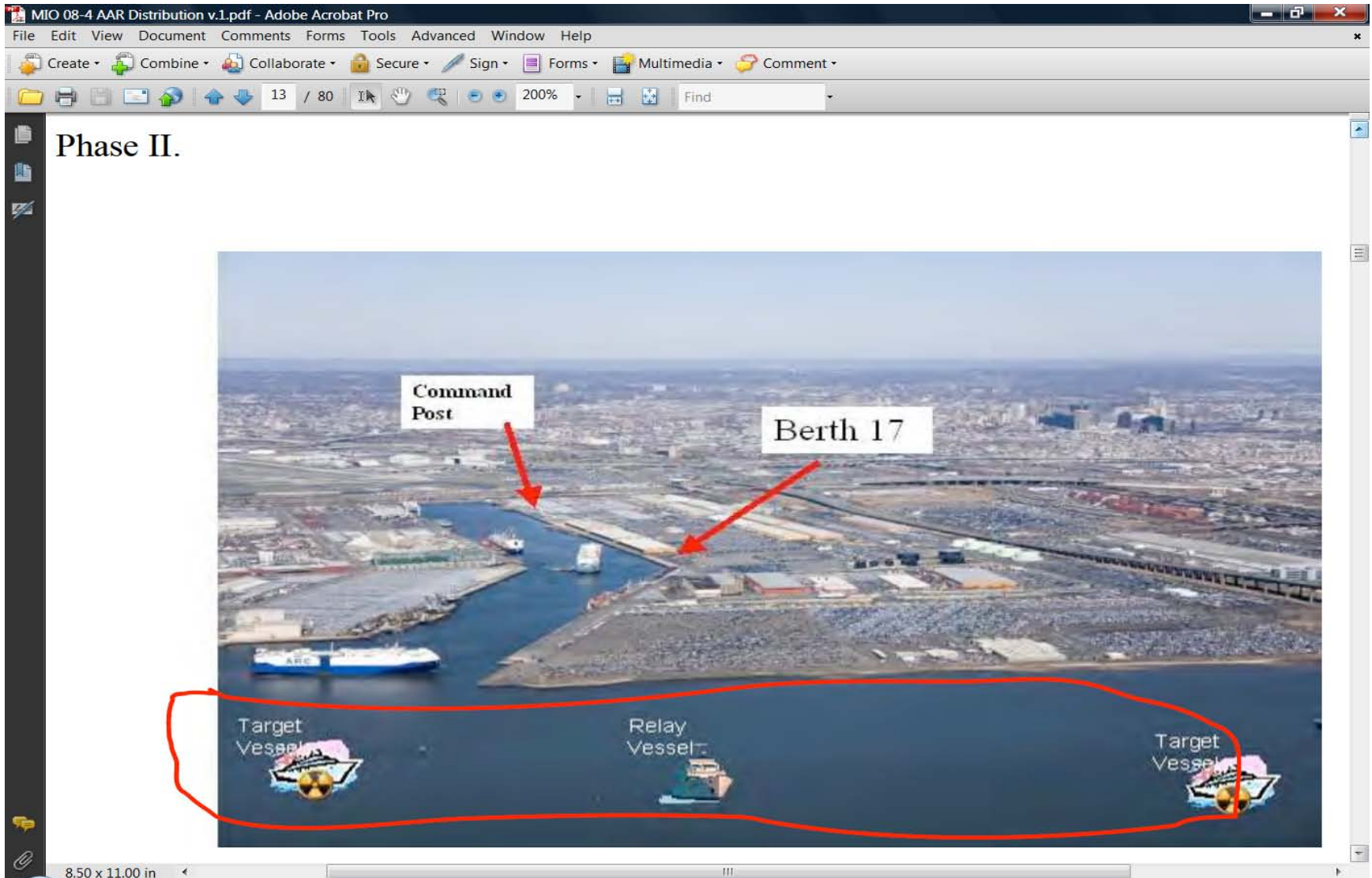


TNT MIO Testbed in action providing on-the-move network to multiple boarding parties searching a large cargo ship and reachback to PANYNJ EOC and DoE expert centers.





Simultaneous small craft search in Port of Newark, Sweden, and Denmark and data sharing operations





Sharing PANYNJ JSAS SA View of NJSP security vessel underway to target vessel drive-by detection

JSAS Executive Viewer - Windows Internet Explorer

https://jsa.rjan.org/jsa/

File Edit View Favorites Tools Help

JSAS Executive Viewer

New York and New Jersey Metro Region

Christopher Vann Open

Display Broadcast Forms Layers

Map Timeline Feeds Documents Geolocator

Vessel 8352 - Color

Color Camera - Vessel 8352

9/9/2008 12:08:33 PM

Map

Feeds

- NPS - MIO
 - Team 1
 - Team 2
 - Team 3
 - Office - Monterrey
- NJSP
 - Vessel 8352 - Color
 - Vessel 8352 - IR
- PANYNJ
 - Port Newark
 - Port Newark Trailer
 - Holland Tunnel
 - PATH
 - PAPD1 Helo
- Air Traffic

Date	Incident	Headline	Severity	Category	Code	Agency
Sep 09 08 12:07	EXPERIMENT MIO DAY 2	*Exercise* Fireboat Firefighter underway12:05	Unknown	CBRNE	Alert	NPS
Sep 09 08 12:04	EXPERIMENT MIO DAY 2	Simulated biometrics event USCG cutter underway 11:59	Unknown	CBRNE	Alert	Vendor
Sep 09 08 12:02	EXPERIMENT MIO DAY 2	***Experiment*** NJSP Boat Video Feed Available	Moderate	CBRNE	Intelligence Report	PANYNJ
Sep 09 08 12:02	EXPERIMENT MIO DAY 2	***EXERCISE*** BIOMETRIC DATA FROM	Unknown	CBRNE	Alert	NPS

Done

Start 4 Interne... 3 Groove... C:\Documen... Presentation2 Google Earth Search Desktop 9:08 AM

Receiving shared USV drive-by search results in PANYNJ and NPS TOCs: Network controlled USV Piraya in action at Karlskrona, Sweden



View of shared PANYNJ JSAS small vessel interdiction event COP at the TOC in Karlskrona, Sweden





TNT Testbed: Layered interfaces for integrating models, tools, and experimentation procedures



- The TNT *tactizens* can integrate their sensors and mesh networking elements in the unclassified but closed IP space of the TNT testbed by getting fixed IPv4 and lately IPv6 addresses. Figure 10 illustrates the online portal enabling rapid integration of experimental assets in TNT testbed IP space,
- Users can connect their remote local area network, including command and operation centers, via the virtual private network (VPN) client on top satellite or commercial IP cloud services,
- Sensors and unmanned vehicles can be integrated with the TNT Situational Awareness Environment via the applications layer interoperability interface. The current option includes Cursor-on-Target (CoT) integration channel, initially developed at MITRE (Miller, 2004), comprised of the CoT message router and CoT XML adapters for each node needed to be integrated



TNT Testbed: Layered interfaces for integrating models, tools, and experimentation procedures



- In the very near future we will consider adding the Common Alert Protocol (CAP), which is becoming widely used by the DHS community,
- Human layer interface: Operators (both remote and local) can access the testbed collaborative environment via the collaborative portal or peer-to-peer collaborative clients, situational awareness agents, video conferencing room , and video client.
- At the physical level the testbed reaches to even lower levels (like multiple mesh network enabled unmanned systems), which permit researchers to experiment with such things as airborne sensors and cooperative control without having to be concerned about network connectivity.



Plugging IP assets in the TNT Testbed: IP Space Portal

(Designed by Eugene Bourakov)

http://cenetix.nps.edu/SA1/ipconfigmain.asp - Windows Internet Explorer

http://cenetix.nps.edu/SA1/ipconfigmain.asp

Google 8 Search Bookmarks Find Check AutoFill Sign In

Convert Select http://cenetix.nps.edu/SA1/ipconfigma...

TNT Host IP configuration



The following subnets are currently configured to support TNT experimentation:

- Bay Area MIO 192.168.72.xx
- Wireless ITT Mesh Bay Area 192.168.73.xx/24 (mask 255.255.255.0)
- TNT subnet 192.168.98.xx/23 (mask 255.255.254.0)
- TNT subnet 192.168.99.xx/23 (mask 255.255.254.0)
- OFDM backbone subnet 192.168.100.xx
- Wireless ITT Mesh 192.168.112.xxx/25 (mask 255.255.255.128)

Fill in the following field(s) to match the search criteria:

Host IP	Node Name	MAC address	Description
1			

Search

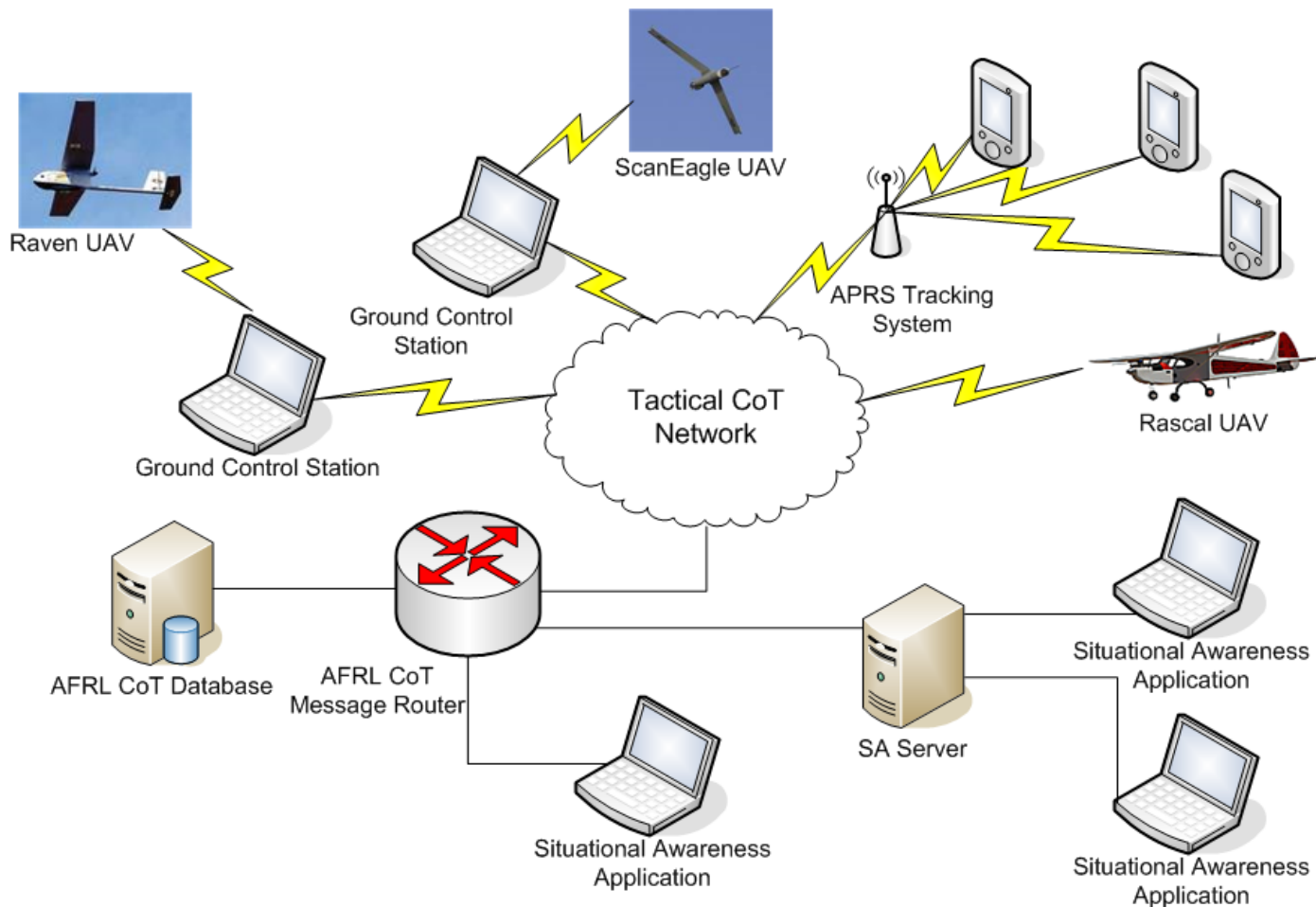
Administration

Back to CENETIX Portal.

Internet | Protected Mode: On 100%

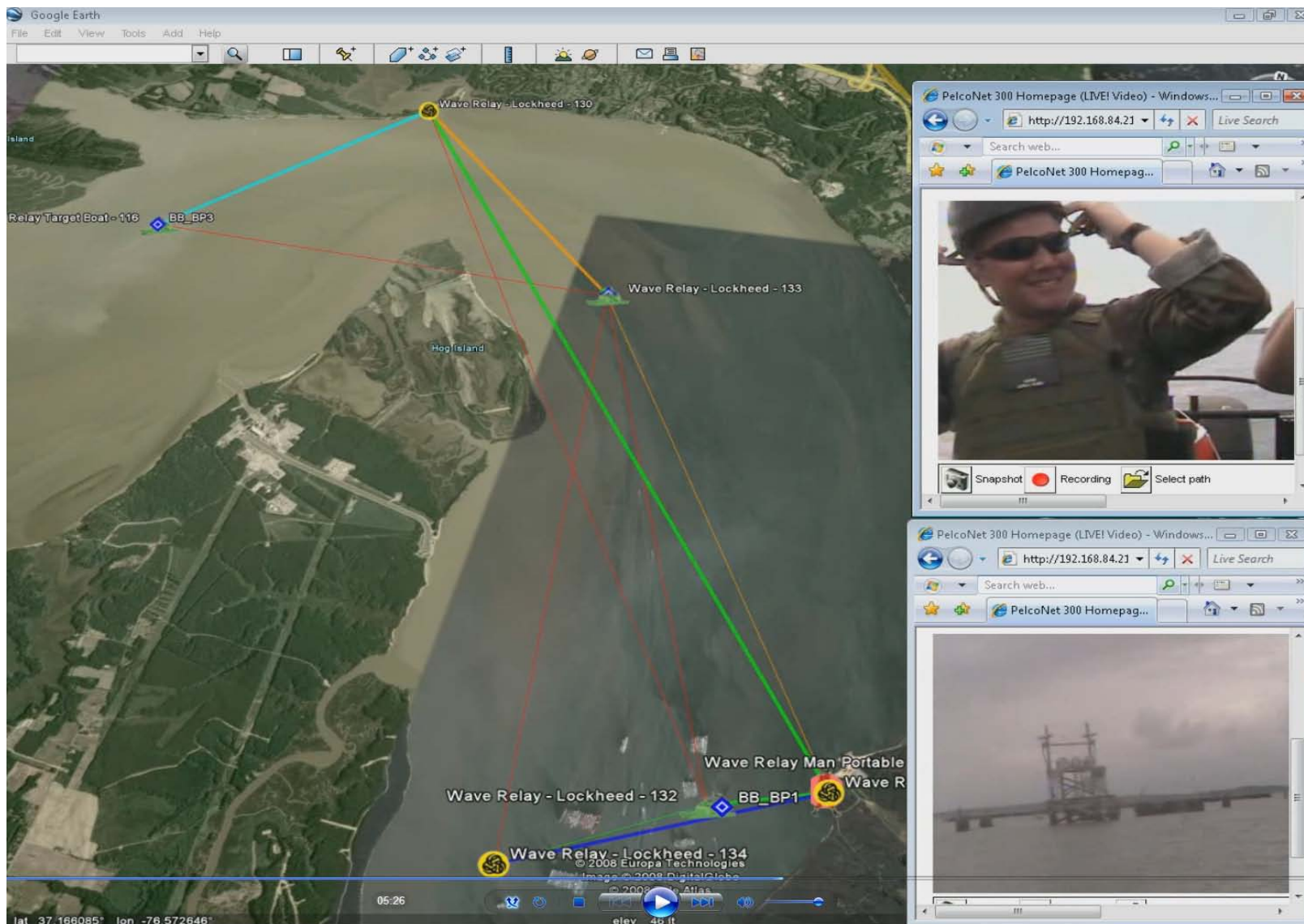
Applications Layer Testbed Interface via the CoT channel

(Diagram provided by Michael Clement)



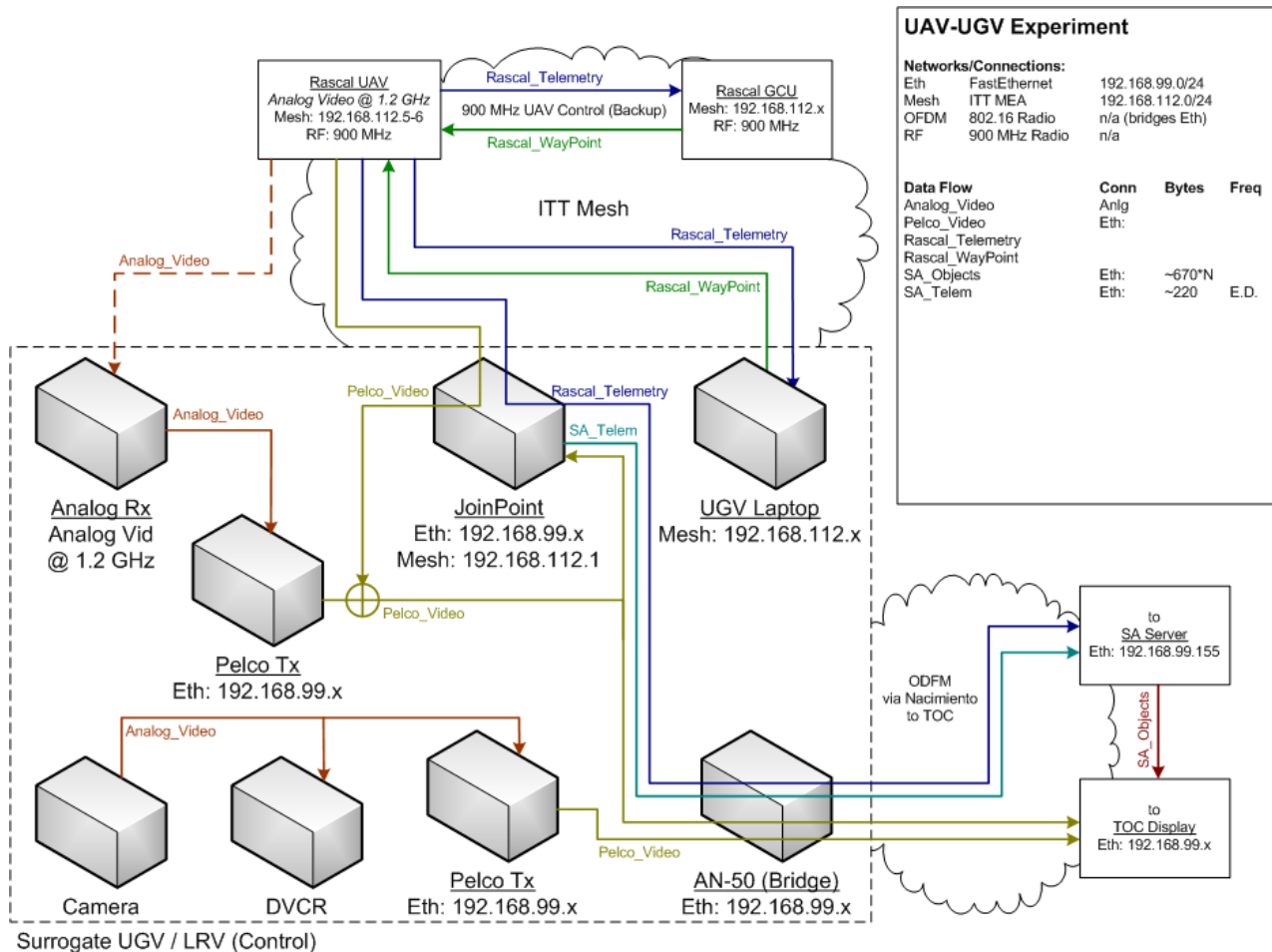


Operator interface: video clients and SA View in the Riverine Operations

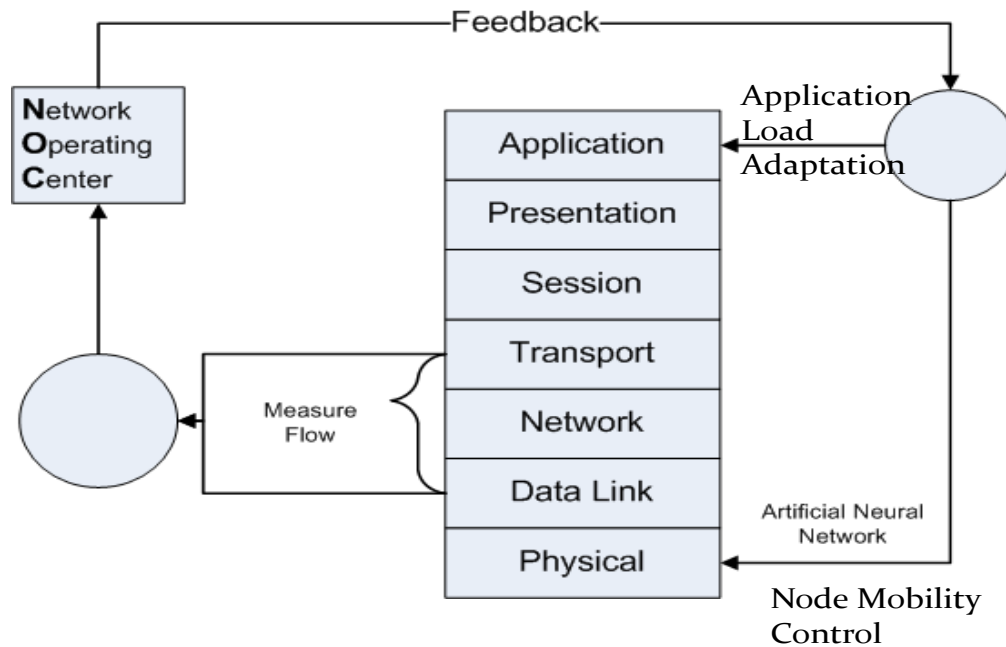


Mesh network interface enabling cooperative control of UAV and UGV

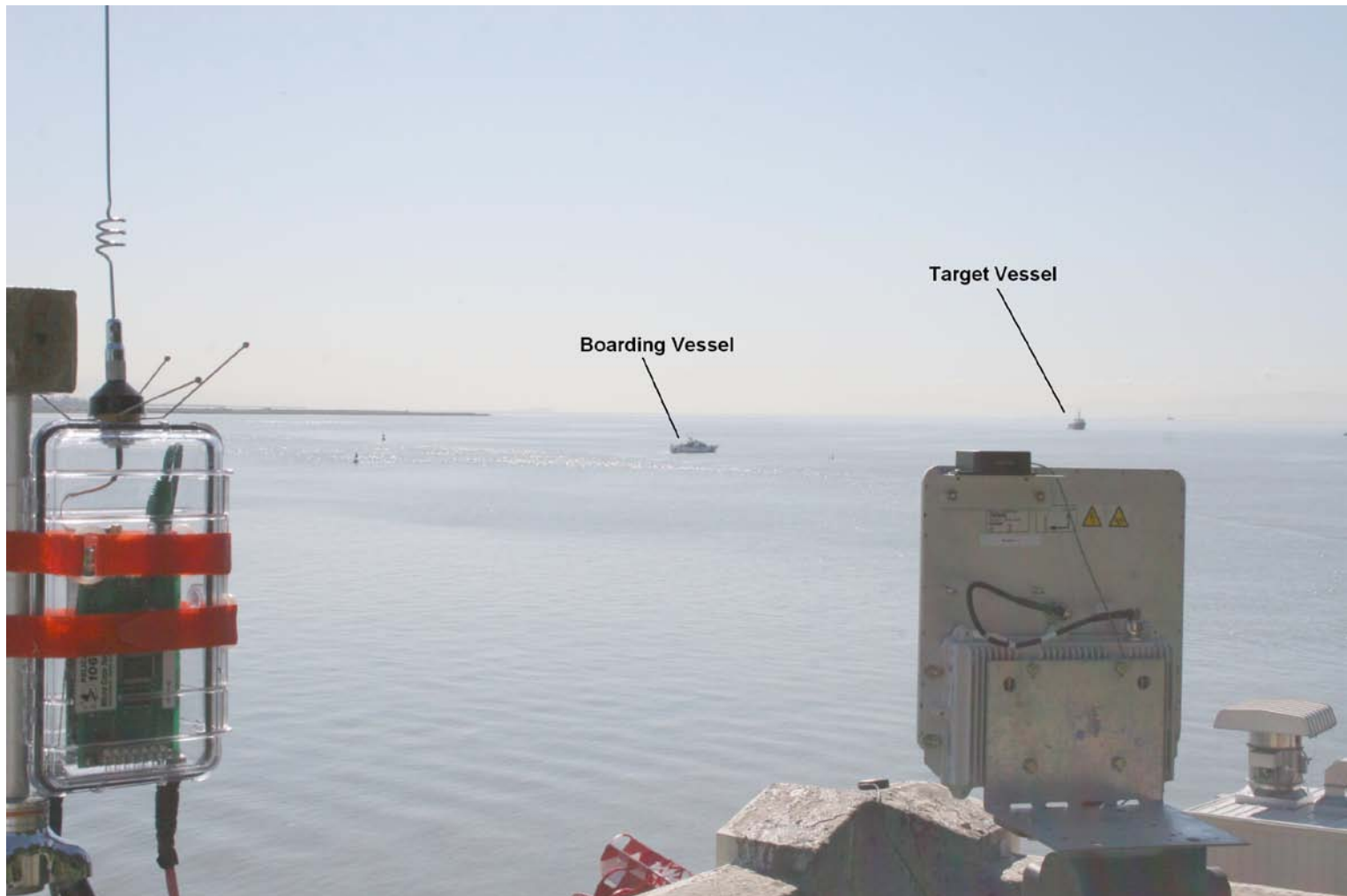
(Diagram provided by Michael Clement)



Layers of Adaptation in TNT Testbed



Physical Layer Adaptation: Self-Aligning Ship-to-Ship and Ship-to-Shore Networking Nodes (with Eugene Bourakov)

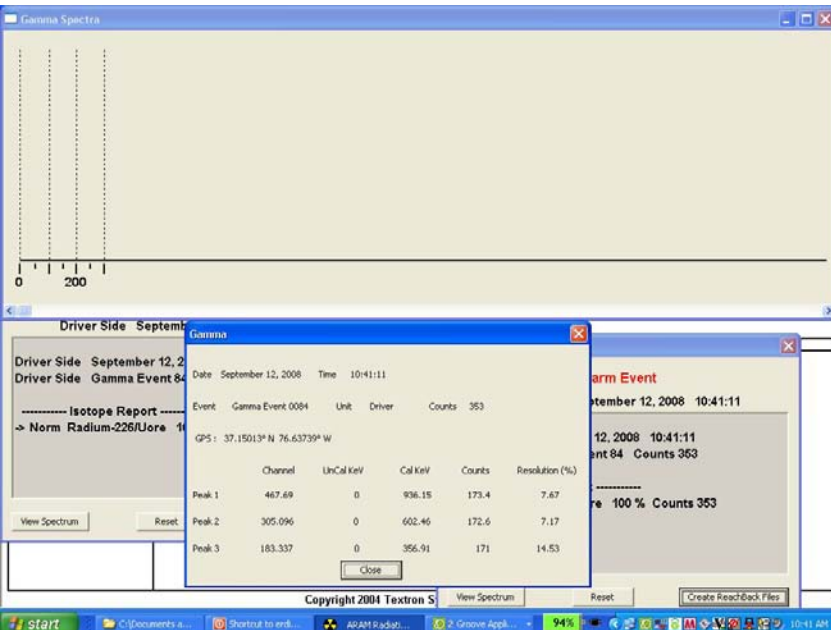




Application load adaptation during collaboration with remote experts while in the Riverine chase at high speed



Radiation scan taken by Boarding Vessel #1 and subsequent discussion in Groove shared workspace



MIO 08-4 - Discussion - Groove

File Edit View Format Options Help Workspaces

Discussion

New Topic Response

Date	Subject	Author
9/11/08 11:12 AM	boats are moving really fast	Little Creek/Naval Postgraduate School
9/11/08 11:14 AM	BB2 on station	ARAM-CP2/Naval Postgraduate School
9/11/08 11:20 AM	BB2 Biometrics reports subject Brian submitted for identification	ARAM-CP2/Naval Postgraduate School
9/11/08 11:26 AM	BB2 report ARAM CP2 DETECTS RADIUM 226 REQUEST REACHBACK	ARAM-CP2/Naval Postgraduate School
9/11/08 11:27 AM	Re: BB2 report ARAM CP2 DETECTS RADIUM 226 REQUEST REACHBACK	Dave Trombino/Naval Postgraduate School
9/11/08 11:29 AM	Re: BB2 report ARAM CP2 DETECTS RADIUM 226 REQUEST REACHBACK	Little Creek/Naval Postgraduate School
9/11/08 11:34 AM	Re: BB2 report ARAM CP2 DETECTS RADIUM 226 REQUEST REACHBACK	ARAM-CP2/Naval Postgraduate School
9/11/08 11:25 AM	Spectra files posted by ARAM search boat	Dave Trombino/Naval Postgraduate School
9/11/08 11:50 AM	Re: Spectra files posted by ARAM search boat	Dave Trombino/Naval Postgraduate School
9/11/08 11:30 AM	BB2 Biometrics reports positive ID on subject Brian, TCN 910068	ARAM-CP2/Naval Postgraduate School
9/11/08 11:30 AM	BB2 BIOMETRICS captured record on TOM - local bad guy hit TCN 910069	ARAM-CP2/Naval Postgraduate School
9/11/08 11:32 AM	Re: BB2 BIOMETRICS captured record on TOM - local bad guy hit TCN 910069	Dave Trombino/Naval Postgraduate School
9/11/08 11:35 AM	Re: BB2 BIOMETRICS captured record on TOM - local bad guy hit TCN 910069	ARAM-CP2/Naval Postgraduate School

BB2 report ARAM CP2 DETECTS RADIUM 226 REQUEST REACHBACK
by ARAM-CP2/Naval Postgraduate School on Sep 11, 2008 11:24:12 AM Modified on Sep 11, 2008 11:26:06 AM

FILES POSTED TO folder ARAM CP2 event 74

Workspace Members

In Workspace

- NPS_NOC/Naval Pos...
- Dave Trombino/Naval Po...
- John Looney/Naval Post...
- Little Creek/Naval Postgr...

Online

- Peter Guest/Naval Postgr...

Offline

- ARAM-CP2/Naval Postgr...
- Bryan Huggens/Naval Po...
- Jeffrey Oik
- Jonas Hedlund
- Kent Meyer
- Kodjums TOC/Naval Post...
- LLNL Reachback/Naval P...
- Marianna Verett/Naval P...
- Mike Clement/Naval Post...
- Mike Ferebee/Naval Post...
- MIO HQ C2 (4th Seat)/N...
- Richard Bergin/Naval Pos...
- Yaara Bergin/Naval Post...

Invite to Workspace: More

Enter name or email: Go

Chat

5:28 AM
good Friday morning
NPS_NOC/Naval Postgraduate School: 9/11/2008 5:30 AM
Good morning - NPS NOC online

Common Tasks

Networking Frontier: Self-forming agile adaptive networks

Unmanned systems-sensor-decision maker cooperative networks

- **Self-Organizing Mesh Wireless Networks**
TNT Reports from 2005-2008
- **Network and SA controlled UAVs, USVs, UGVs:** Unmanned vehicle is controlled by submitting the way points via tactical N-LOS mesh network. An ongoing study with Bourakov, Clement, Jones, Dobrokhodov, Kaminer (Clement, et.al., 2009) and (Jones, et. Al., 2009)
- **Network-on-Target:** Peer-to-peer links configured from the top of Common Operational Picture interface, self-aligning directional antennas (Bordetsky & Bourakov,2006)
- **Hyper-Nodes with 8th Layer:** Tactical Self-Forming nodes as miniature network operations centers (Bordetsky & Hayes-Roth, 2007)
- **DMs as sensors to unmanned systems:** Operators decision space MIB available to the unmanned system agents. First results accomplished in the thesis project of LCDR James Gateau, (Gateau &Bordetsky, 2008)
- **Networking-by-touch:** Transmitting data via highly adaptive human network by using physical or electronic touch. First results accomplished in thesis of Rideout & Strickland (NPS), continuing research with Bourakov (NPS) Elman (MIT), and Lindeman (WPI):
(Rideout and Strickland, 2007), (TNT 08-2 QLR), (TNT 08-4 QLR)

Adding Unmanned Systems to MIO Network: Drive-by Search by USV, UAV Relay to the Fast Boat, UGV in the Tunnel



USV provided radiation detection in small-boat drive-by with real-time expert reachback; network-controlled USV & UGV

Networking Frontier: Self-forming agile adaptive networks

Unmanned systems-sensor-decision maker cooperative networks:

- **GPS denial navigation** : An ongoing study since 2007 with Bourakov and MIT team (TNT 07-4 QLR, 2007), (TNT 08-2,QLR 2008)
- **Ultra Wideband (UWB) Mesh networking**: Integrating the UWB link into the peer-to-peer wireless mesh network. An ongoing study with Bourakov (NPS), Win and Weymereesh (MIT) (TNT 08-4 QLR 2008)
- **Projectile-based Networking**
TNT MIO 07-4 After Action Report, 2007
- **Small Distributed Unit Private Tactical Satellite Network**: Study started in 2007, first results accomplished in thesis project of MAJ Conrad and LCDR Tzanos (Conrad and Tzanos, 2008)
- **Small Distributed Unit Private Tactical Cellular Network**: Study with Bourakov started in 2008 (TNT 08-4 QLR, 2008)

Collaboration Frontier: Collaborative Networks for Interagency Data Sharing and Synergy of Social and Information Networking

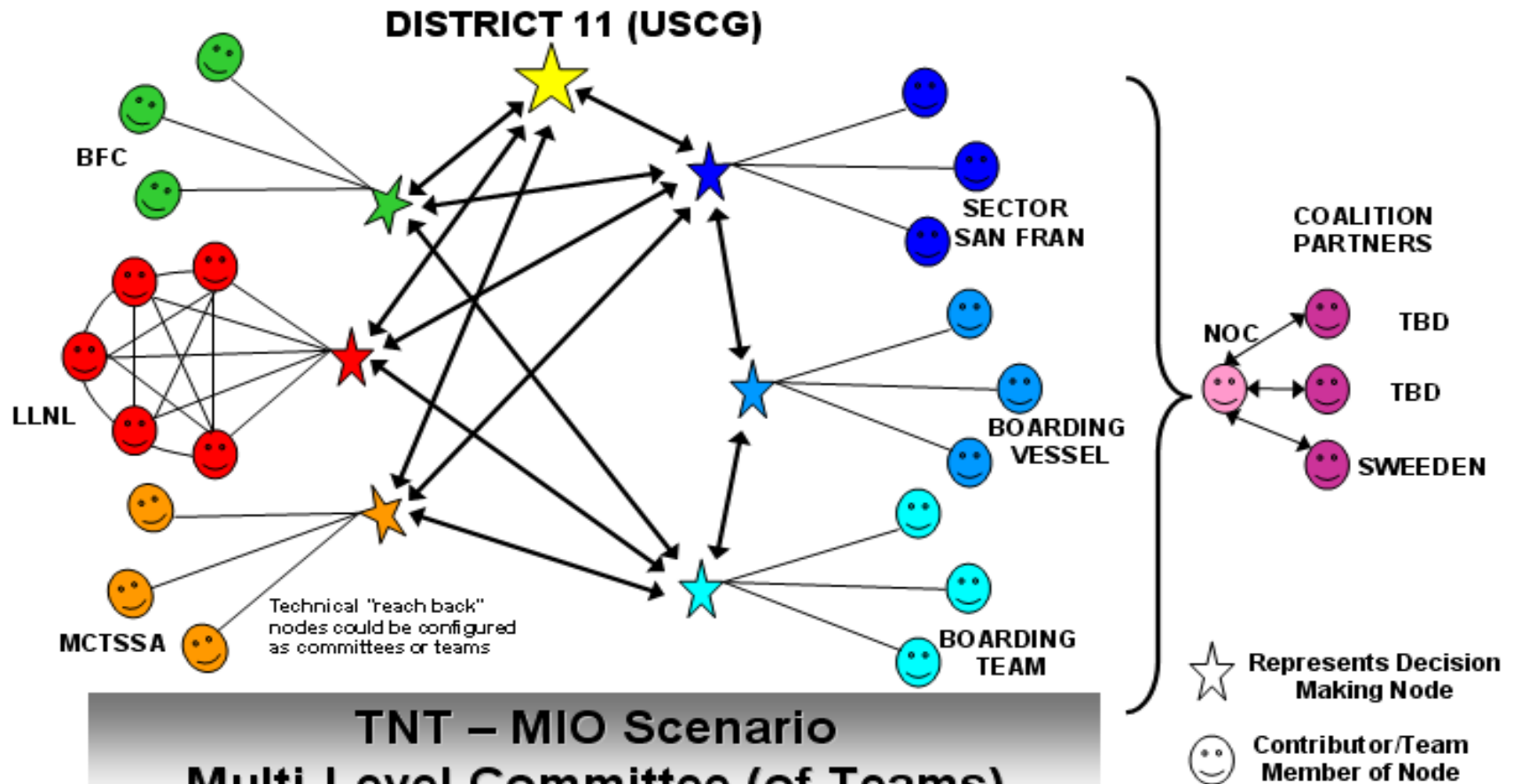
- **MIO Collaboration:** Bringing the remote expert advice to an immediate support of the boarding officers
 - Collaborative networks for rapid interagency data sharing.** An ongoing research with Dougan & Dunlop (LLNL), Bourakov, Hutchins, Looney, Clement , Vega , Hudgens, Bergin-NPS; Friman (Swedish Defence Research Agency), Pickl (University of Bundeswehr)): (Bordetsky et al, 2006), (Hutchins, et.al., 2006), (Bordetsky & Friman, 2007), (Bordetsky & Hutchins, 2008),
 - Synergy of social and information networking:** With Hudgens, Vega, Koons, Bergin, Bekatoros: (Hudgens and Bordetsky, 2008), (TNT MIO 08-4 Report)
- **SA and Collaborative platforms interoperability:** Propagating alerts between NPS SA tools, Port Authority NY-NJ (PANYNJ) Joint Situational Awareness System (JSAS)
 - Collaborative networks for rapid interagency data sharing:** First results accomplished with Bourakov and Clement (NPS), Reimers (BAE), Poulsen and Cooper (PANYNJ), Lindt (Kokums, Sweden), Hoy-Petersen and Nielsen (Systematik, Denmark): (TNT MIO 08-2 Report, 2008), (TNT MIO 08-4, Report, 2008)
- **Collaboration with Coalitions partners**
 - Synergy of social and information networking:** SNWC BFT-NPS SA-JSAS (with Hansson & Lindt (Sweden) -Danish MBS-NPS SA-JSAS (with Hoy-Petersen, Nielsen, and Riderring-Systematik, Denmark)

Interagency Collaboration: Cargo Vessel Search by Multiple Boarding Parties in SF Bay Area and Seven Small Craft Drive-by Search





MIO 06-4 Collaborative Network (Captured by students: Rideout and Dash)



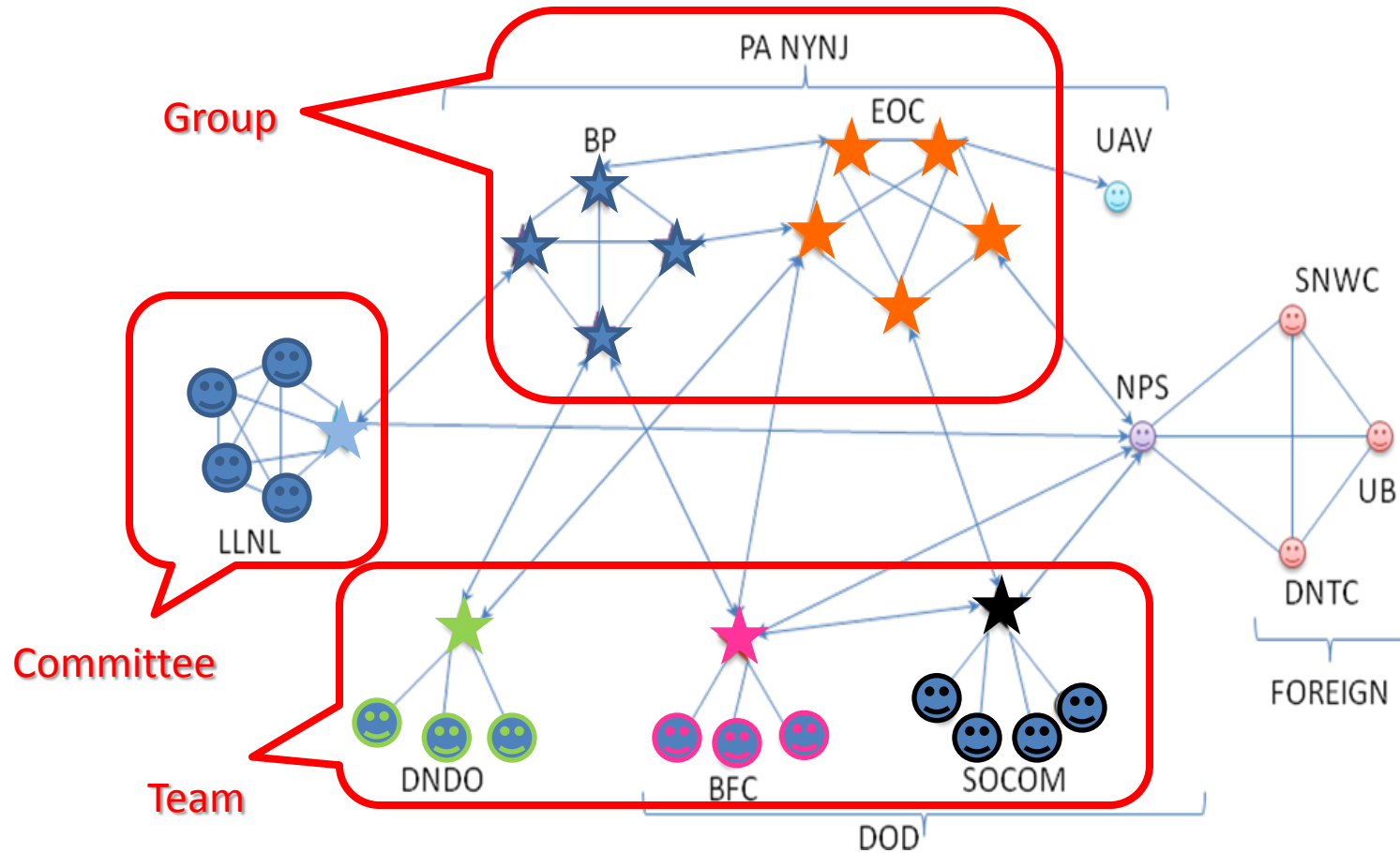
TNT – MIO Scenario Multi-Level Committee (of Teams) Decision Support (DS) Structure

Multiple DMs with complete participant interaction at multiple levels in the chain of command.



MIO 08-4 Experiment: Collaborative Network Topology

(Captured by students: Masacioglu, De Soto, Chang)





Conclusion: Enabling Business Process of Synergy Development

- Quarterly experiments, supported by student and faculty experimentation services, allow the TNT *tactizens* (vendors, academic, and other government partners) to rapidly adapt their solutions to the TNT environment
- A unique collaborative environment in which the innovation of participants often results in additional unscheduled experimentation using combined technologies.
- The shortest adaptation cycle is 3-4 days of rapid team design during the TNT experiment.
- The next level cycle includes 8-10 weeks of research projects delivering feasibility or constraints analysis experiments.
- The longer adaptation term is in conjunction with dedicated student thesis project (about 6 months).



Conclusion: An Incubator of Tactical Networking and Collaboration Solutions for Vendors

- Quarterly experiments, supported by student and faculty experimentation services, allow the TNT *tactizens* (vendors, academic, and other government partners) to rapidly adapt their solutions to the TNT environment
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Conclusion: An Incubation Path to Tactical Networking and Collaboration Solution Vendors

- To the business community the TNT testbed research services and interfaces enable discovery and constraints analysis for frequently immature and disintegrated prototypes
- Testbed provides a unique incubation path to the market of emerging tactical operations

Industrial Participation		
Adaptive Flight	I-C Mobilisa	Remote Reality
AGI	iGov Technnologies	Restech
Amrel	ImSAR	Retica
AOptix	IST-Textron	Sarnoff
Applied Signal Technology	L-3 Com	Space Data Corp.
BAE Systems	LMCO	Step Labs
Blackbird Technologies	McLane Adv. Technologies	Strategic Initiatives
CDI	Metson Marine	Swe-Dish
CHI	Mission Technologies	Toyon Research
Commsfirst	Mitre	Trident Tech. Solutions
CrossMatch	Networx	TrellisWare
DRS	NGC	Triggerfinger
ESRI	Orion Networking	WinTech Arrowmaker
Extreme Endeavors	P&LE	XTAR
General Dynamics	Persistent Systems	
Harris RF Comms	Procerus	
Honeywell	QinetiQ	
Hoyos	Redline Communications	

Questions?

abordets@nps.edu

(831) 915-2408