TNT Testbed for Self-Organizing Tactical Networking and Collaboration

Dr. Alex Bordetsky, Dr. David Netzer

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.

•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 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

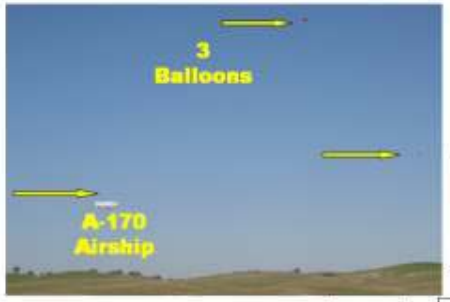
West Virginia – Camp Dawson

Indiana – Camp Atterbury

California (08)

TNT 05-1, Nov 2004

MESH Topology



Ft. Bragg

Tampa

HHMWV Cameral Control

Reach-back

Internet

NOC NPS

7 Videos + SA

TOC CR

Network aware air mesh nodes

Video

Camera GPS Tracker SA

Self forming/ healing

802.11b MESH

Network camera, Rajant Breadcrumb and 802.11b

A-170 Airship

Tethered Balloons: Network camera,Pelco, small laptop, Freewave, GPS, 6 hr batteries

TNT 05-2 Feb 05

Improved Camp Roberts TOC

Cypress Sea Approaching USCGC HAWKSBILL – Radiation Detection

Surrogate Light Reconnaissance Vehicle

VC-6 with TERN UAVs

TERN Network Payload

Balloon Payload

TNT 05-2 Feb 05

NA Sea Nodes

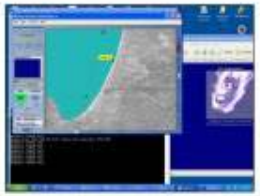
Cypress Sea Support Boat

Cypress Sea NOC

Pelican 802.16/ OFDM Payload

ARIES AUV

SA for Cypress Sea, Pelican, Pelican Video



Resolution Target for EO Performance Prediction

NAVBOARD

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

802.11b or Mesh

ARIES AUV

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).

TNT Testbed

ISR/HVT Operations Segment

Biometrics Task Force, WV

Camp Atterbury, IN

Camp Dawson, WV

VPN / SATCOM

NSWC Dahlgren, VA

NSW Coronado, CA

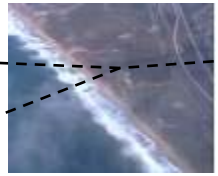
NAWCWD, China Lake

Santa Barbara County Police and Fire

U.C. Santa Barbara

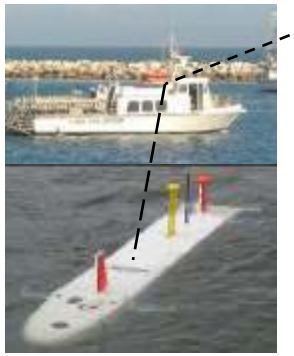
Ft. Hunter Liggett, USAR

802.16



NPS Beach Lab

NOC- NPS CENETIX



Monterey Bay, Pacific Ocean

~100 mi

Camp Roberts ANG

MIO Extension

NPS/CIRPAS McMillan Field UAS Flight Facility

Typical Self-Forming Mobile Mesh Segments of TNT Testbed

Buster
UAS

802.16

LRV at
Checkpoint

Drive-By Detection of Radiation (with LLNL)

Hilltop relay

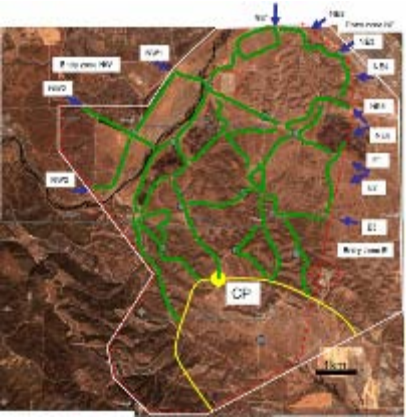
Scan
Eagle

GCS

ITT or
Wave
Relay
Mesh

Self-aligning
802.16

MMALV



Optimized UAS
Search Routes

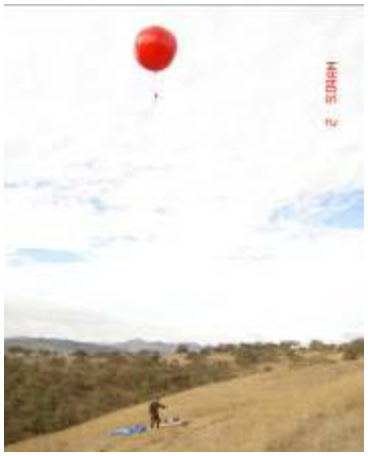
TOC

NPS and/or
Camp Roberts

Swe-Dish and Tachyon

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

UAV and Nano Sensor Augmented Battlefield Medical Scenarios

UAV IPv6 Video

Video

PelcoNet Video Camera

E-Tag Reader

Cell Phone

IPv6 Medical E-Tag Vista

Mannequin

Casualty Site

OFDM 802.16 Link

LRV

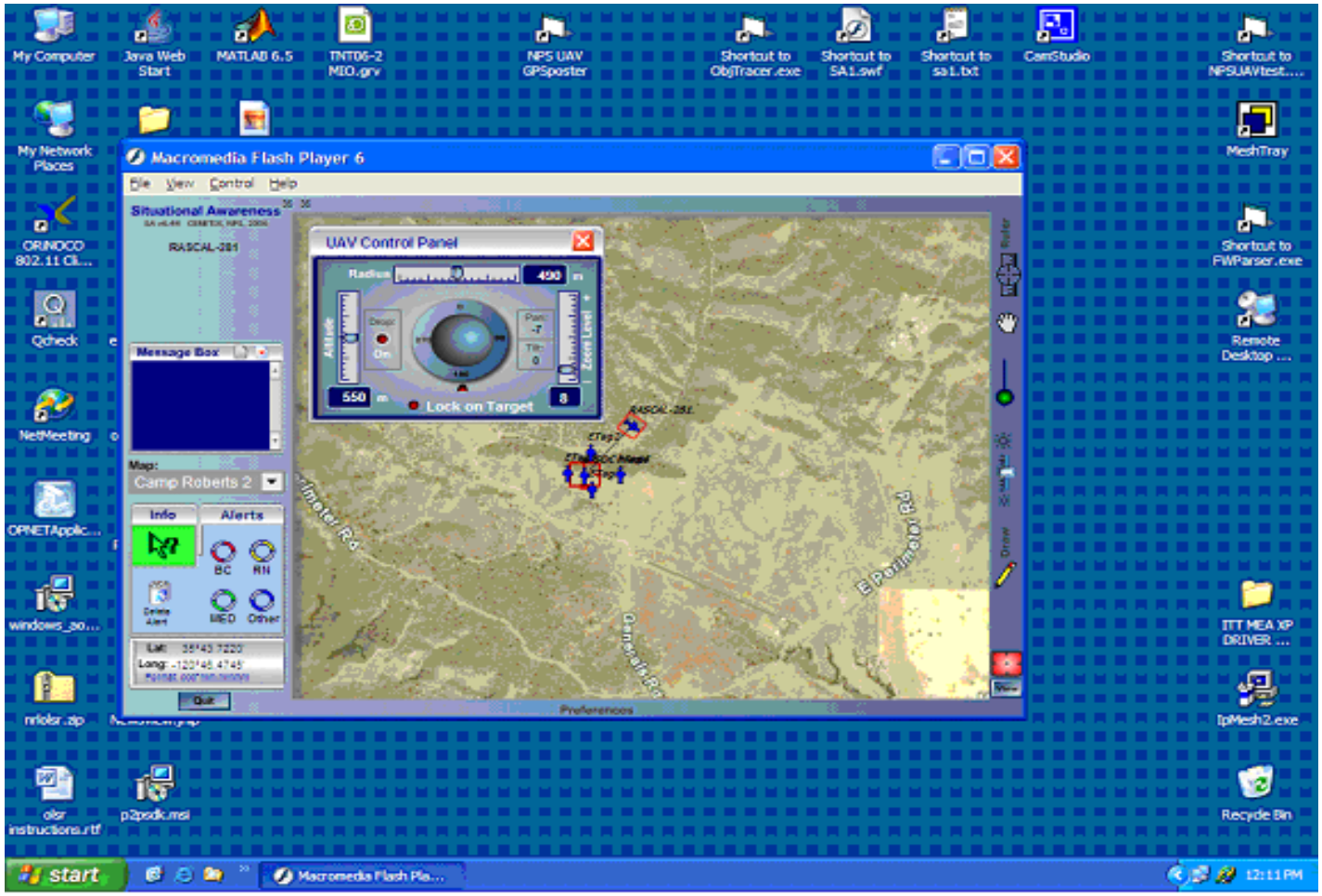
OFDM 802.16 Link

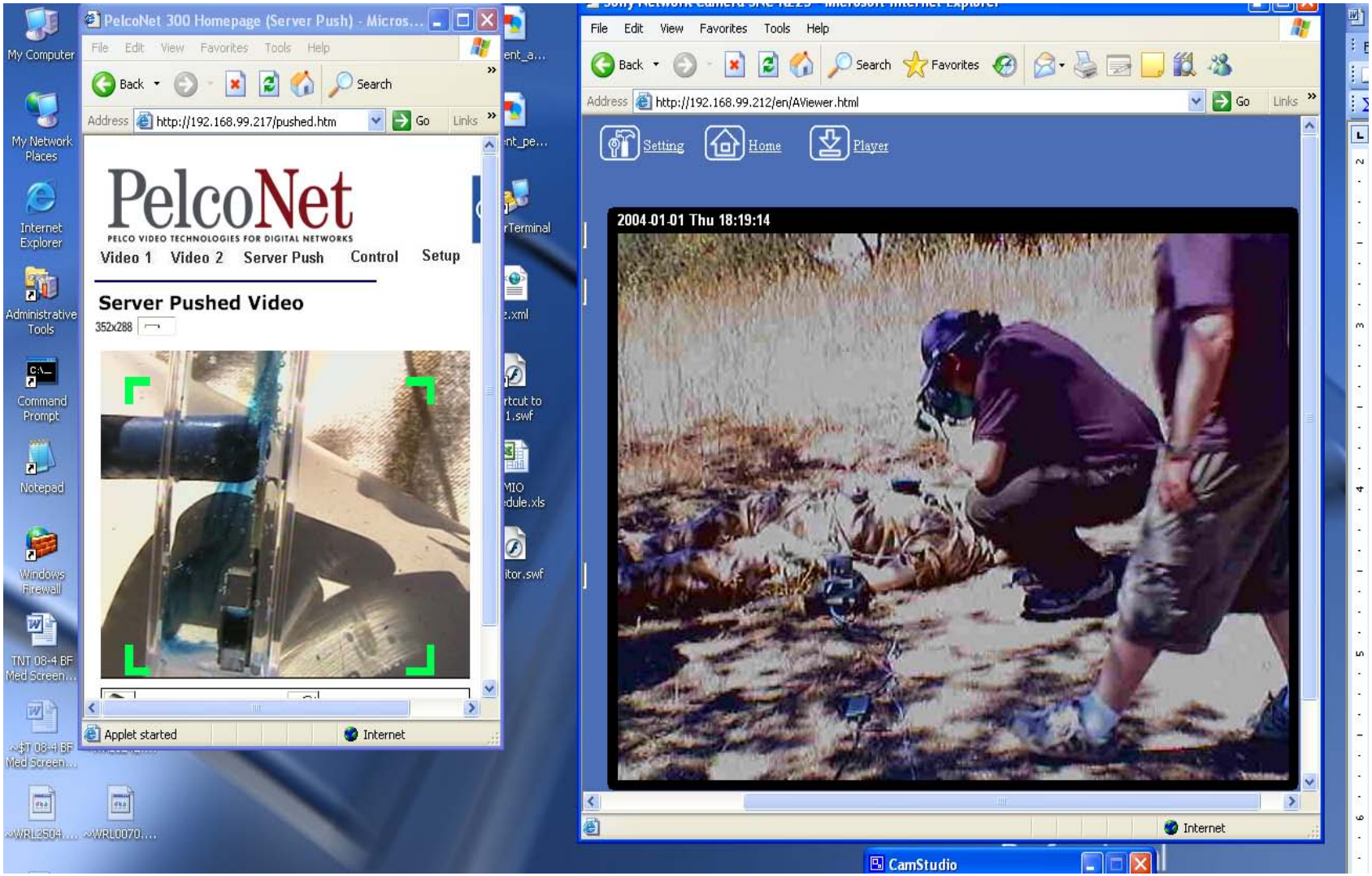
NMS views

IPv6/NPS SA screen/B-TAC health monitor

Network Operations Center

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 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
File Edit View Favorites Tools Help
Back 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
My Computer
My Network Places
Internet Explorer
Administrative Tools
Command Prompt
Notepad
Windows Firewall
TNT 08-4 BF Med Screen...
~$T 08-4 BF Med Screen...
~WRL2504....
~WRL0070....

MIO Testbed Segment: SF Bay, East Coast and Overseas

Pacific Ocean

Sea Fox USV

Self-aligning 802.16

802.16

Riverine - Sacramento Delta

Mt. Diablo

LBNL

NPS CENETIX

LLNL

Port of NY/NJ

U.S.C.G. Yerba Buena Island, CA

VPN / SATCOM

Bay / Port

Fort Eustis, VA - Riverine

San Francisco Bay

NSWC Group 4
LMCO Center for Innovation
VA

Austria, Germany, Sweden, Denmark, Greece, UK, Turkey

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.

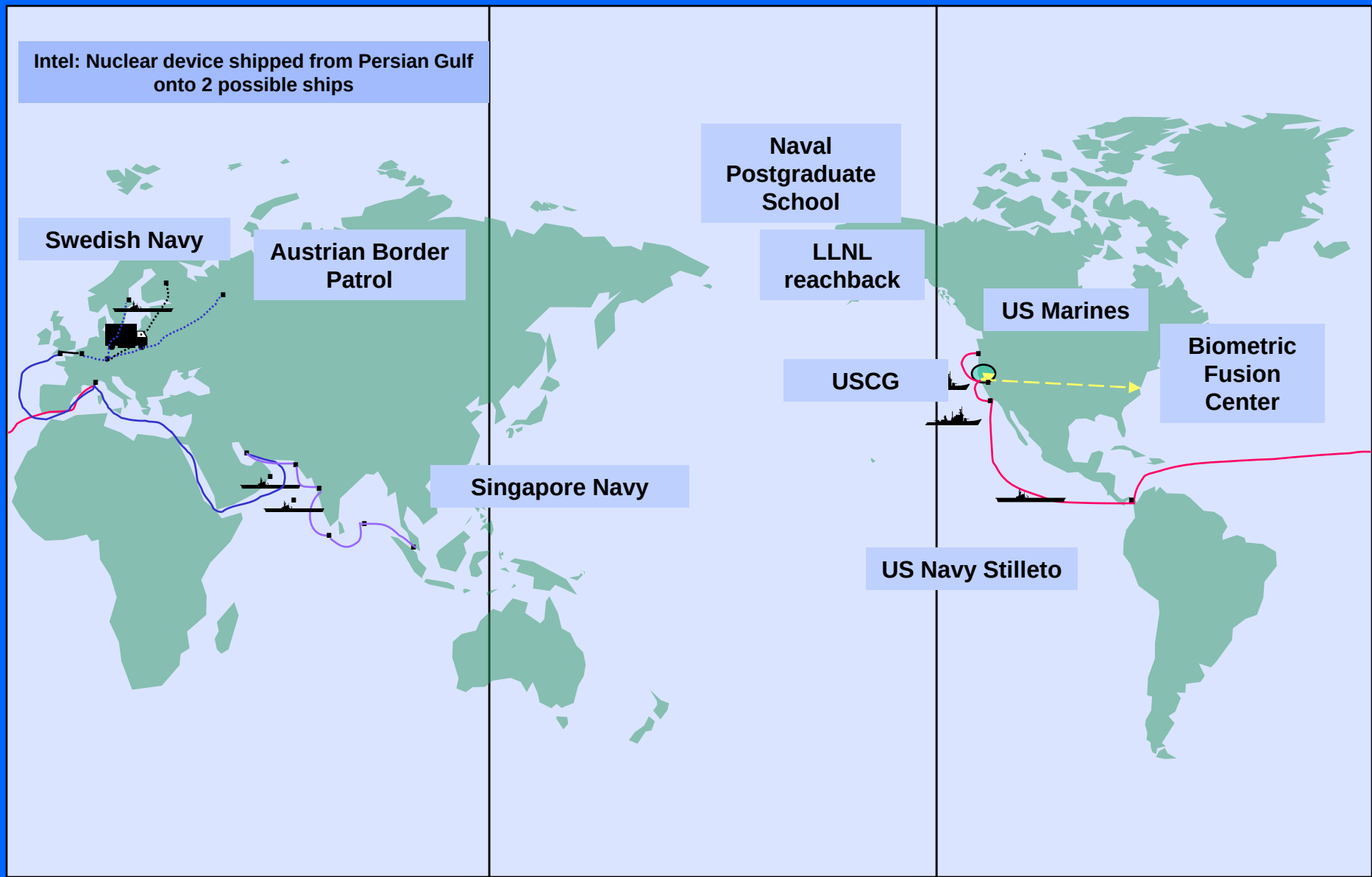
San Francisco Police Dept.

California Office of Emergency Services

Functional Focus of the MIO Testbed Geographically Distributed Teams

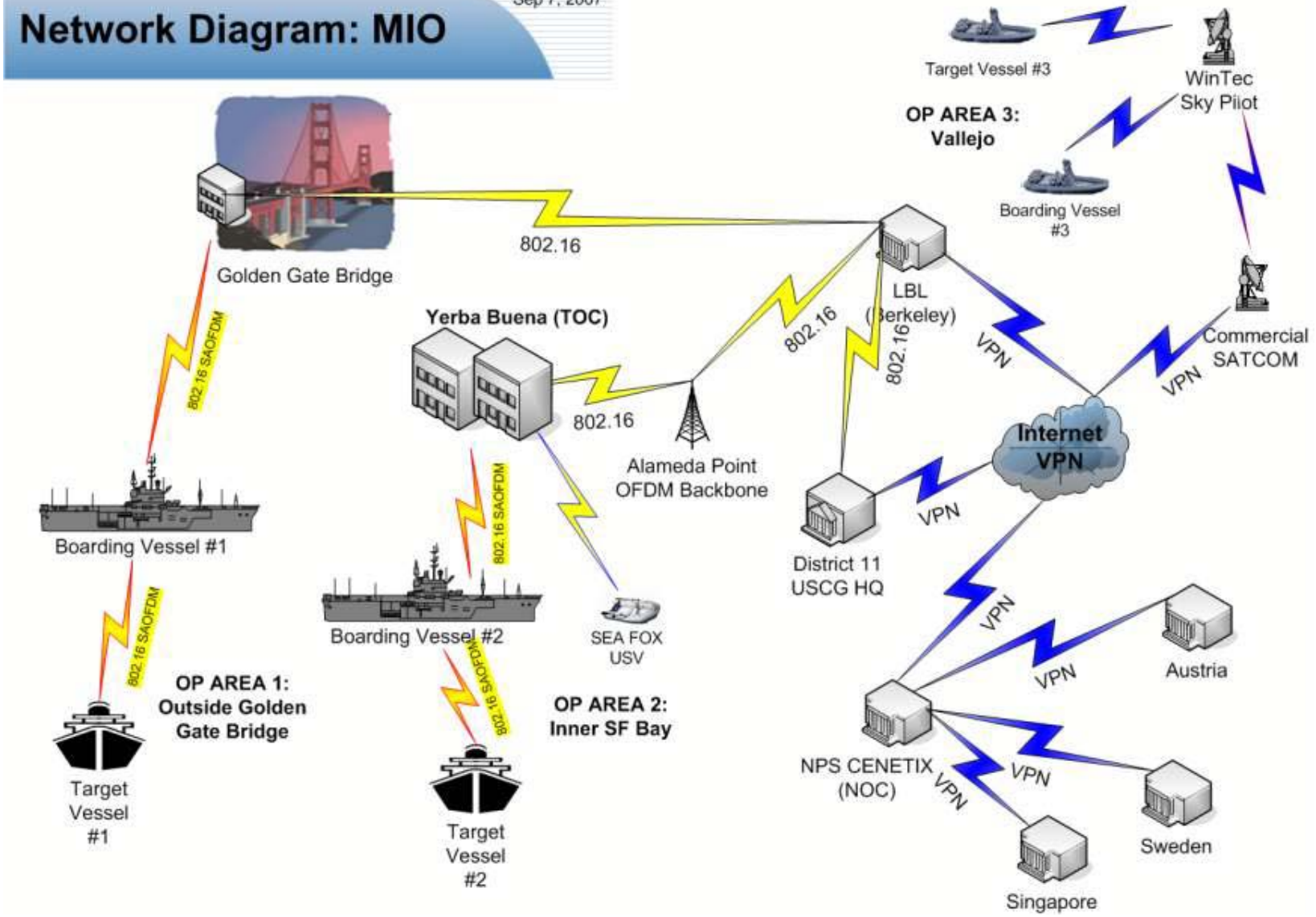
- **San Francisco**: *All new sensor, unmanned systems, and networking technology; data sharing and collaboration with USCG and marine police units, multiple small boat interdiction, DoE reachback*
- **Ft. Eustis:** *Riverine operations, data sharing and collaboration with NSW, USSOCOM, Army Divers*
- **PANYNJ:** *Data sharing and collaboration with NY-NJ area Police and FD first responers, 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



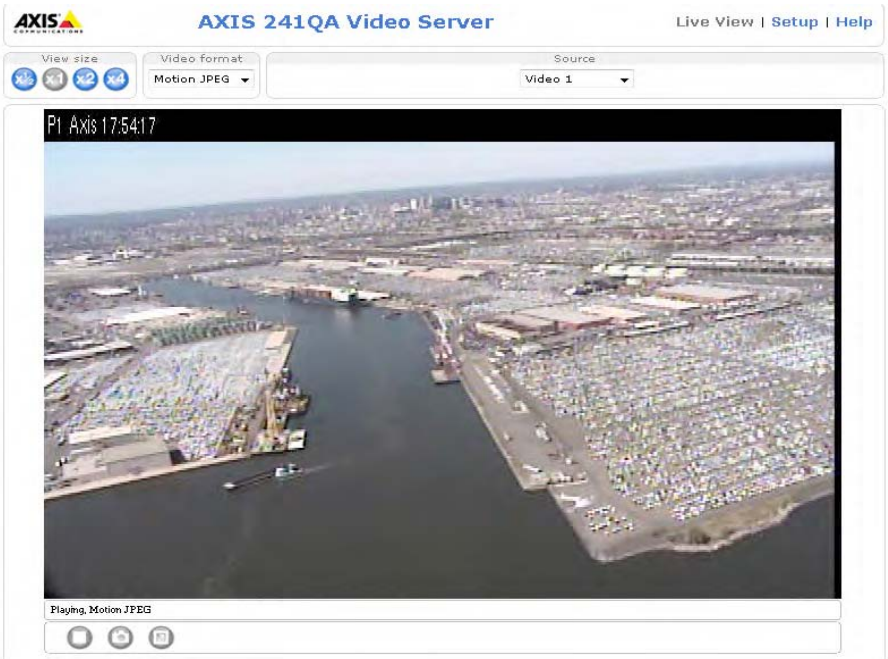
Network Diagram: MIO

Sep 7, 2007



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

MIO 08-4 AAR Distribution v.1.pdf - Adobe Acrobat Pro

File Edit View Document Comments Forms Tools Advanced Window Help

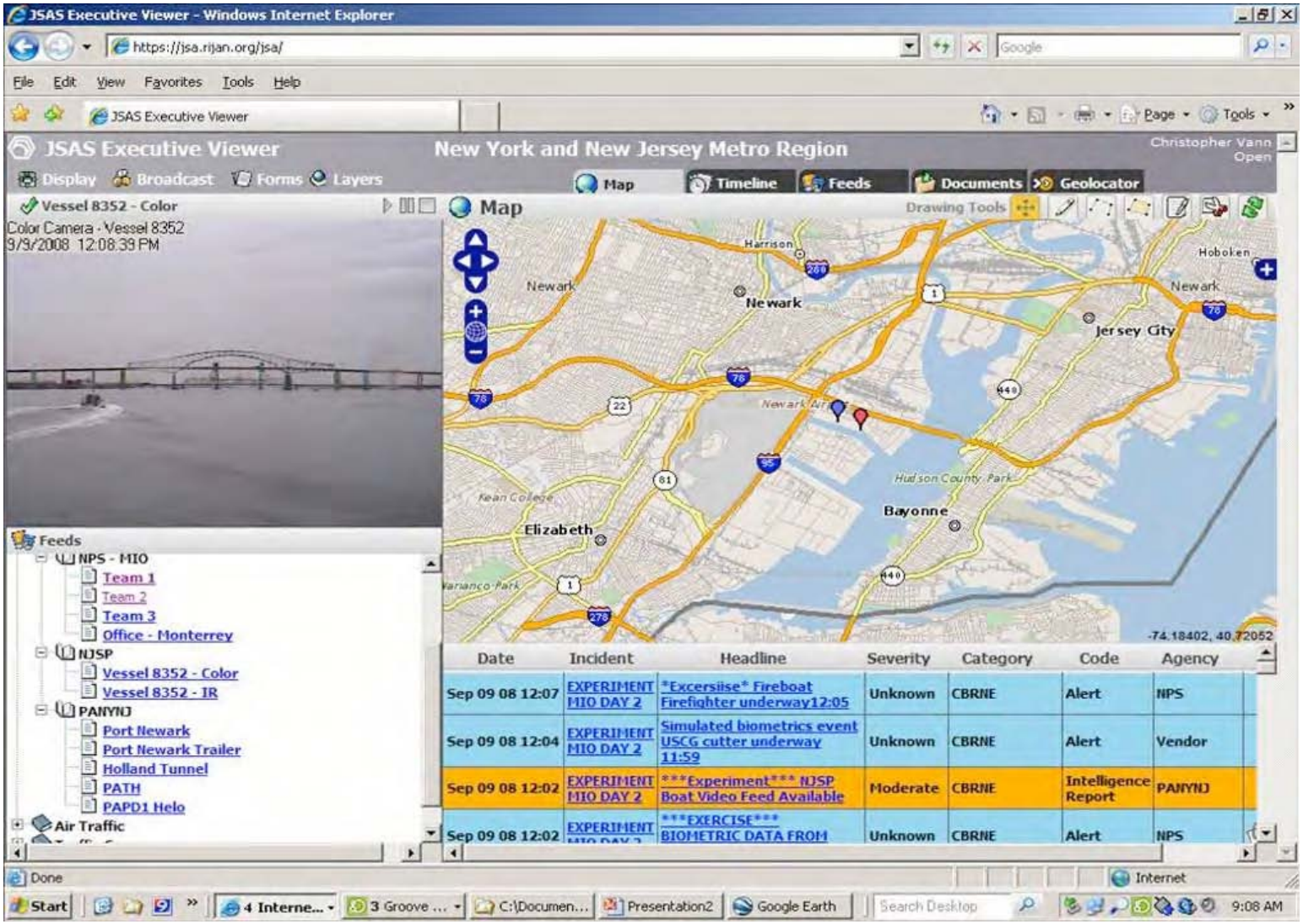
Create Combine Collaborate Secure Sign Forms Multimedia Comment

13 / 80 200% Find

Phase II.

8.50 x 11.00 in

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



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

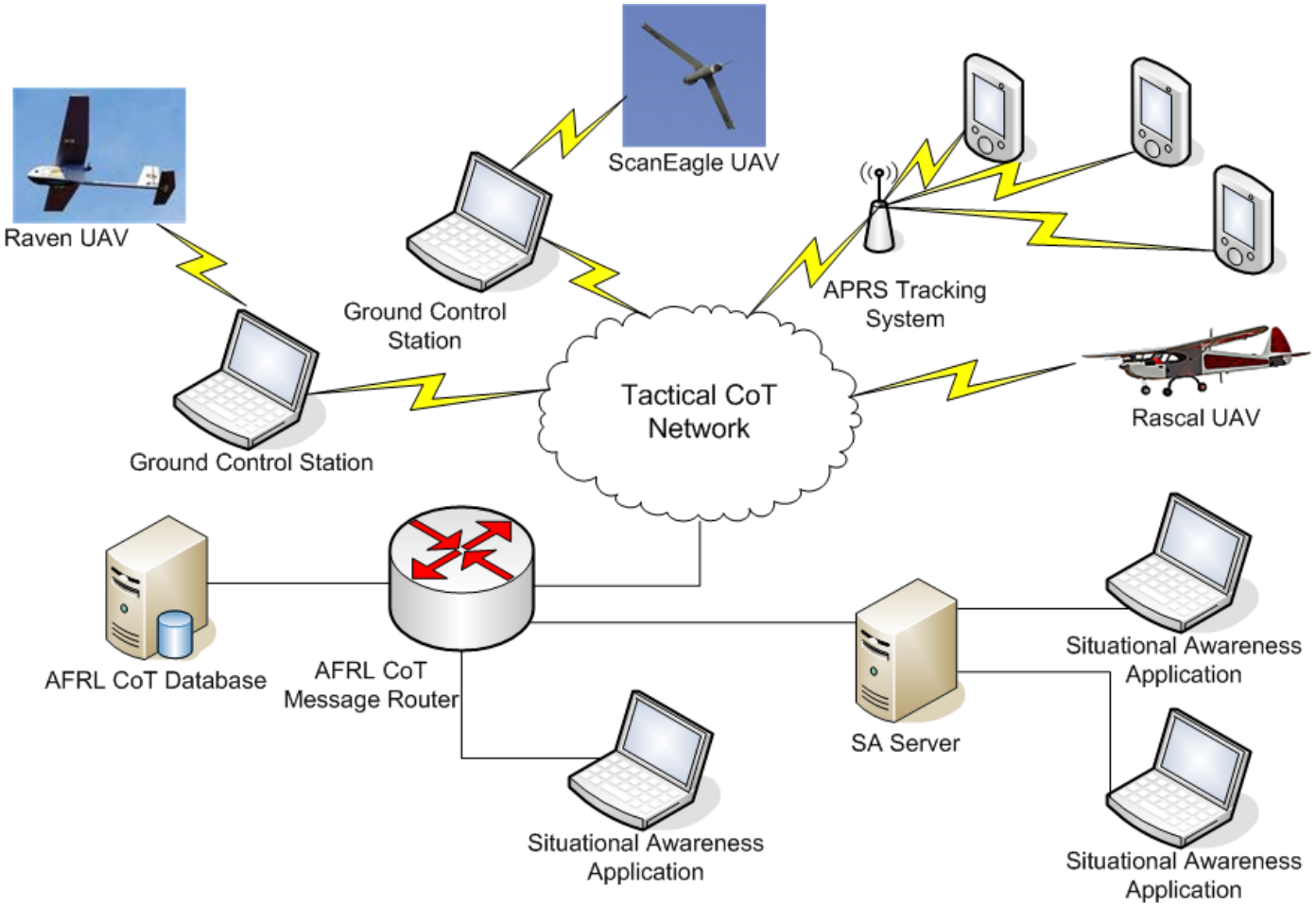
TNT Testbed: Layered interfaces for integrating models, tools, and experimentation procedures

- 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.

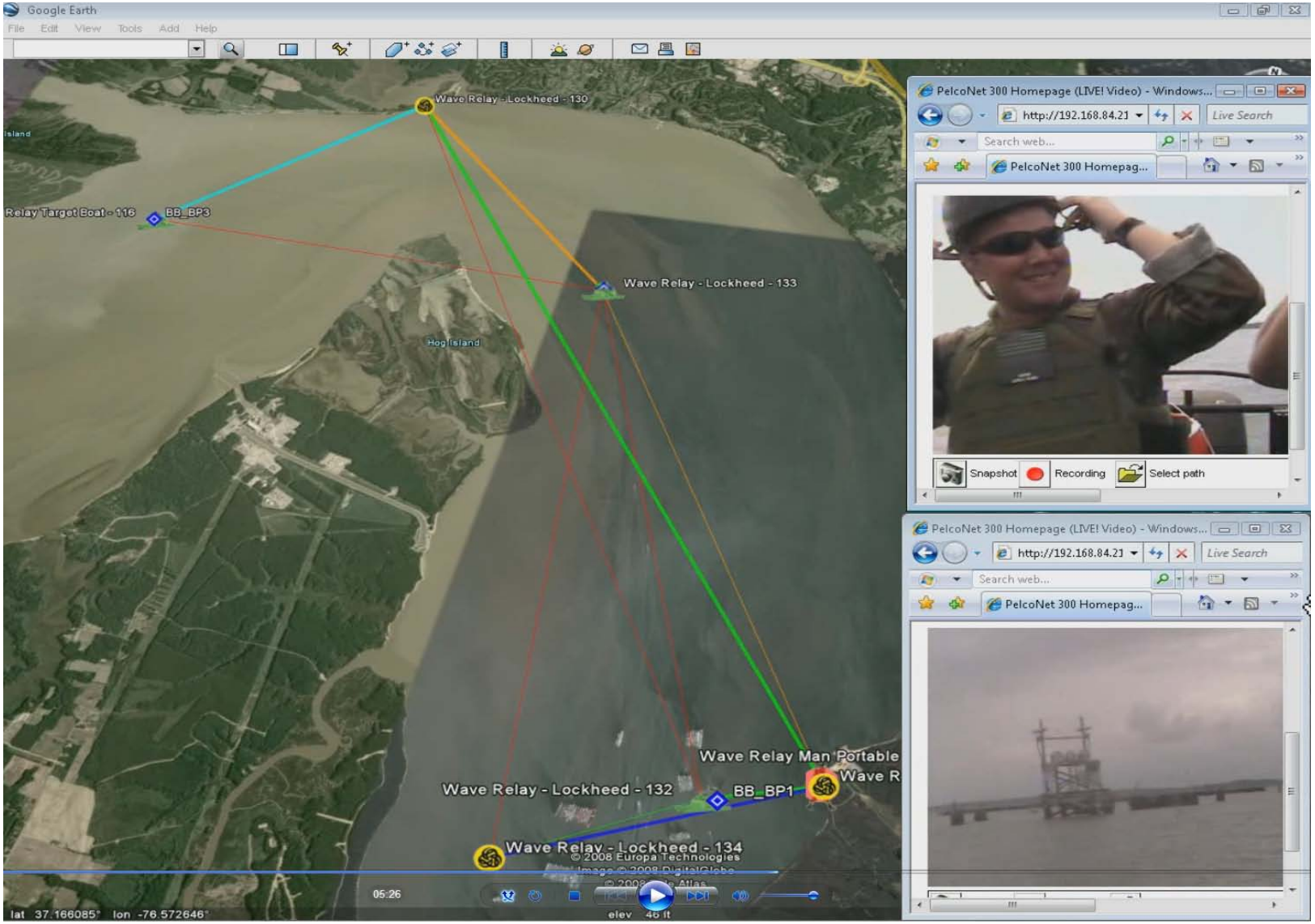
Plugging IP assets in the TNT Testbed: IP Space Portal (*Designed by Eugene Bourakov*)

Applications Layer Testbed Interface via the CoT channel

(*Diagram provided by Michael Clement*)

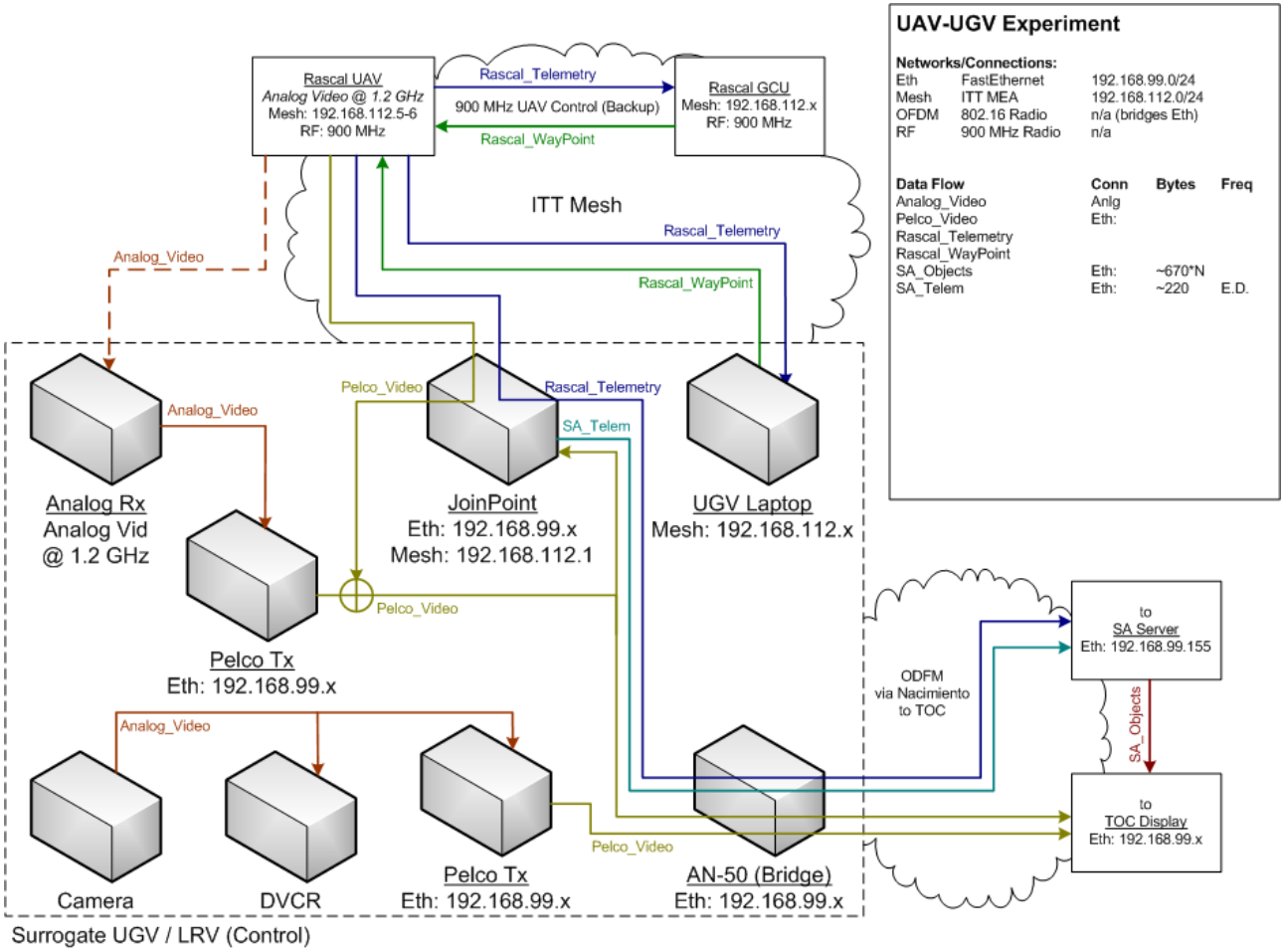


Operator interface: video clients and SA View in the Riverine Operations

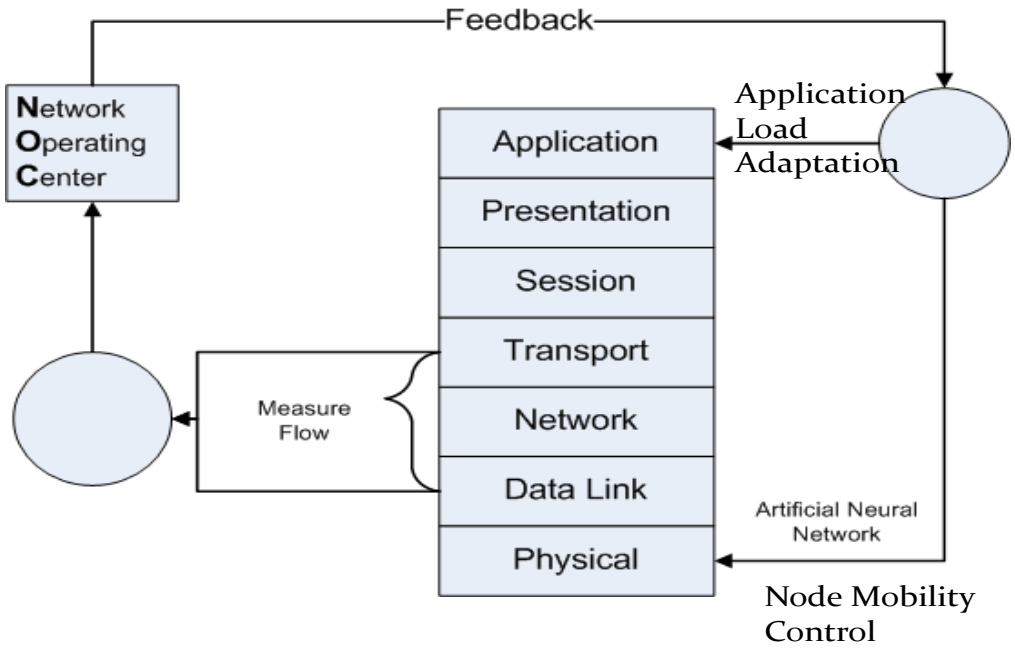


Mesh network interface enabling cooperative control of UAV and UGV

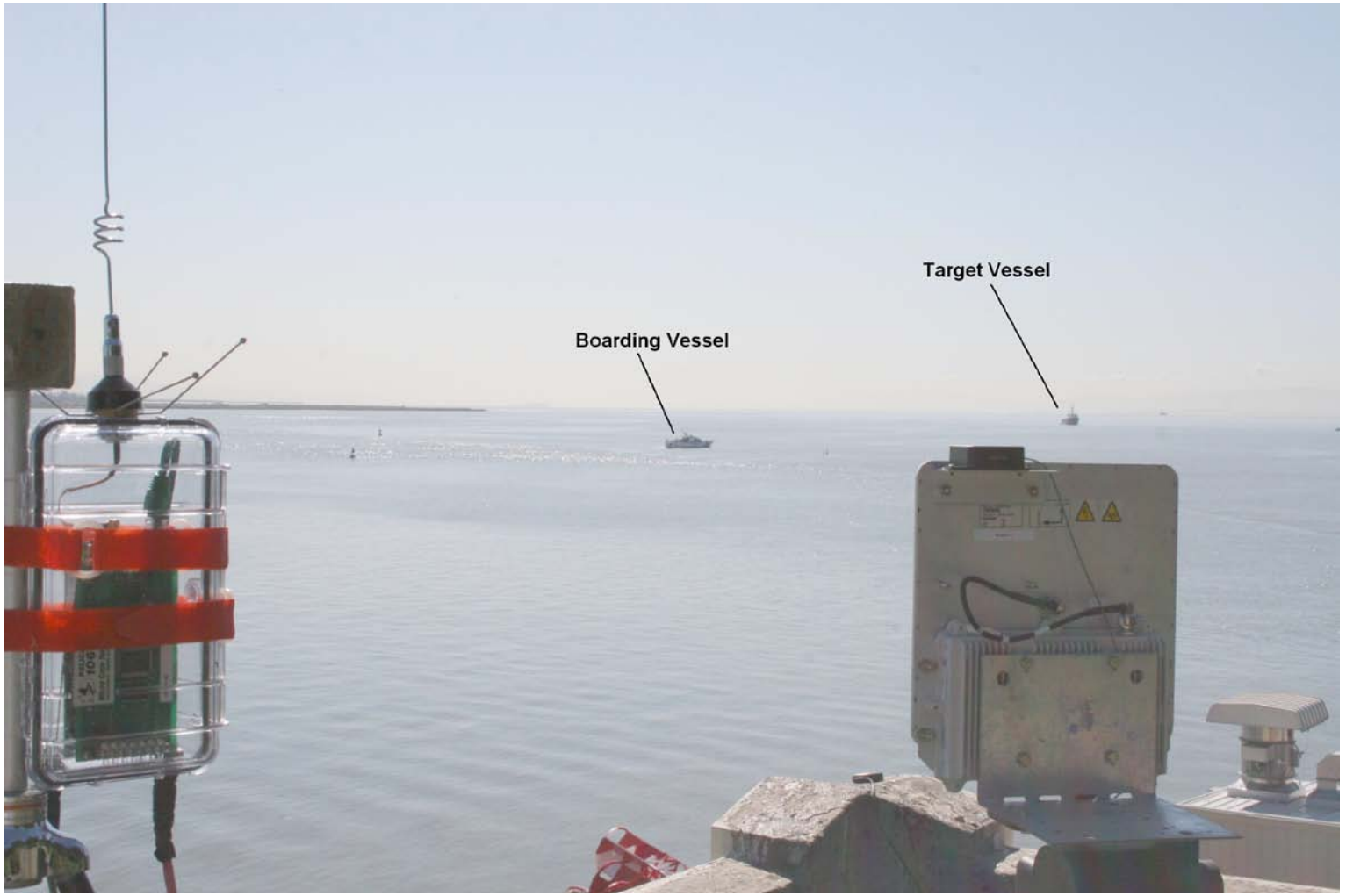
(*Diagram provided by Michael Clement)*



Layers of Adaptation in TNT Testbed

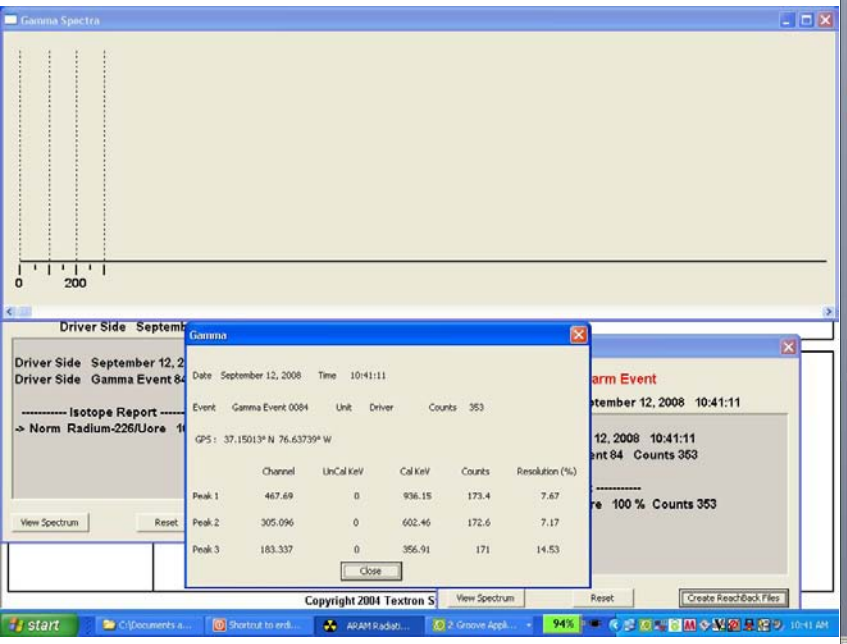


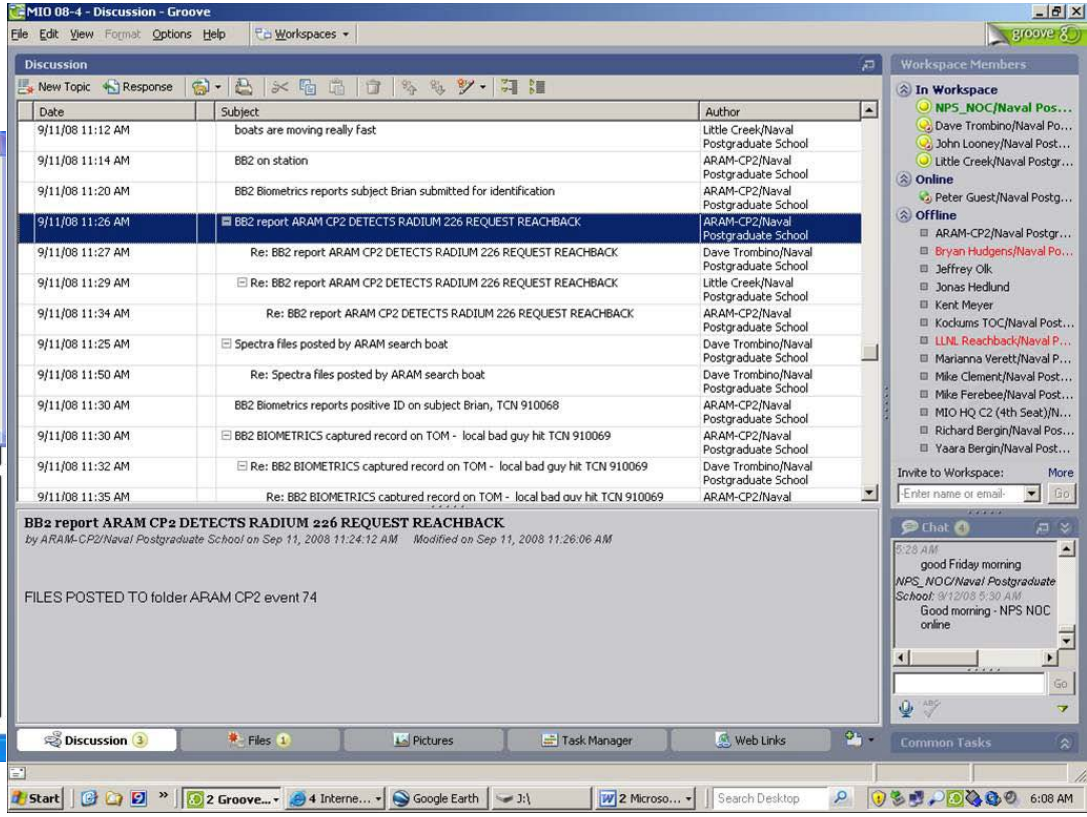
Physical Layer Adaptation: Self-Aligning Ship-to-Ship and Ship-to-Shore Networking Nodes (with Eugene Bourakov)



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





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)

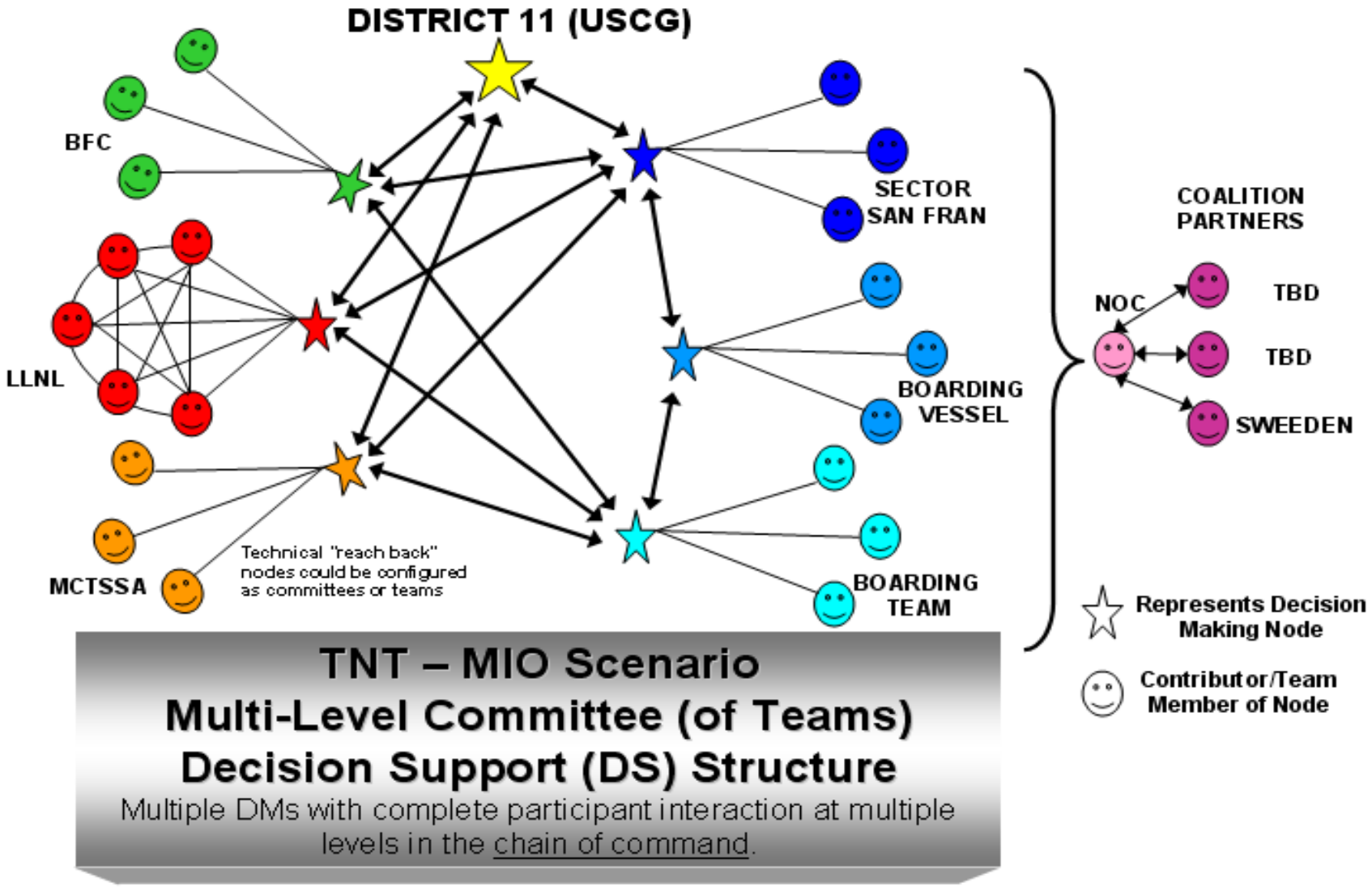
  Collaborative networks for rapid interagency data sharing: First results accomplished with Bourakov and Clement (NPS), Reimers (BAE), Poulsen and Cooper (PANYNJ), Lindt (Kokums, Sweden), Hoy-Petersen and Nielsen (Systematik, Denmark): (TNT MIO 08-2 Report, 2008), (TNT MIO 08-4, Report, 2008)

- **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)

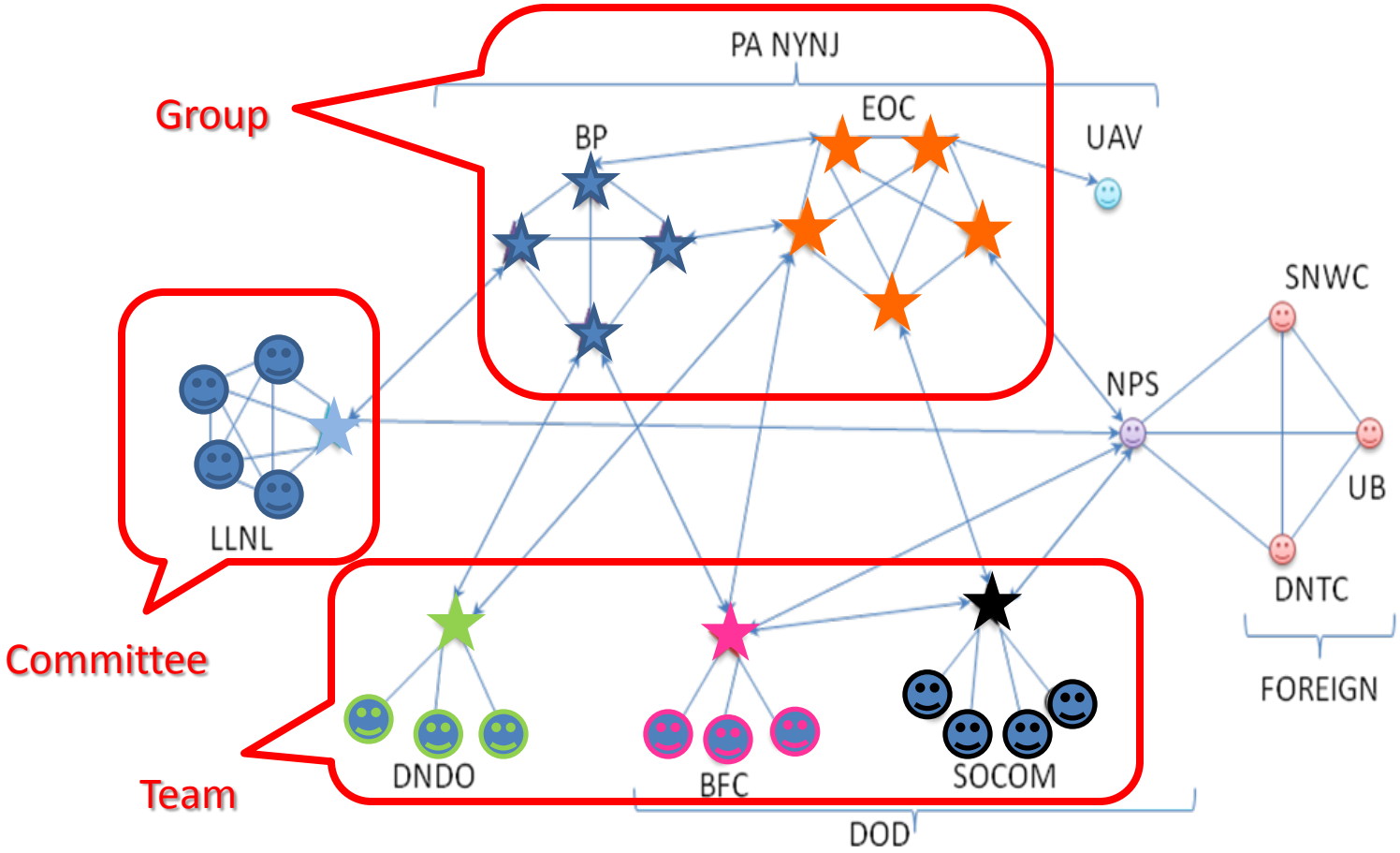


TNT – MIO Scenario
Multi-Level Committee (of Teams) Decision Support (DS) Structure

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
- 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 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