# Hyper-Nodes for Emerging Command and Control Networks: The 8th Layer

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Naval Postgraduate School

11TH ICCRTS
COALITION COMMAND AND CONTROL IN THE NETWORKED ERA
C2 Architectures

# Objective:

- Define new adaptive management concept enabling mobile networking node to become a small-scale Network Operations Center (NOC)

  *Such node could be thought of as hyper-node and it's adaptive self-control NOC functionality as the content of 8th layer in the OSI stack*

- Apply the concept of hyper nodes and 8th layer to adaptive management challenges for self-organizing sensor-unmanned systems-decision maker networks

# Outline

- Background: Tactical Network Topology (TNT) Experiments
- Introducing  set of network operation centers cooperatively  providing feedback to the mobile nodes
- Transferring NOC functionality to hyper-nodes. Making every hyper node network-aware and network operations capable
- Proposed architecture of 8$^{th}$ Layer
- Illustration of 8$^{th}$ layer work in HVT and MIO scenarios

# Background:

# NPS Field Experimentation Program and TNT Testbed

**(with Dr. Dave Netzer in lead, NPS Field Experimentation Program Director)**

# USSOCOM-NPS
# Cooperative Field Experimentation Program

## Large Interdisciplinary NPS Team

**NPS:** - **FY05:** **34 Thesis Students**
**31 Faculty**
**Course Projects: IS, OR, CS**

**Students** - **Joint (Army, Navy, AF, MC)**
**with Operational Experience**

- **8 Departments**
- **2 Institutes**
- **3 Centers**

## Broad DoD and Gov't. Participation and Support

- **USSOCOM**
- **USASOC**
- **AFSOC**
- **NAVSPECWARCOM**
- **JSOC**

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

| | |
|---|---|
| AFRL | BFC |
| DARPA | DTRA |
| LLNL | MARAD |
| NTIO | NRL |
| ONR | OSD/OFT |
| SPAWAR | USCG |
| USN/VC-6 | |

## Industrial Support

**Inter-4**
**Redline Communications**
**Cranite**
**Flarion**
**Mitre**
**WinTec**
**Northrop Grumman**
**Lockheed Martin**
**Brandes Associates**
**Sony**
**SAVY**
**ITT**
**AeroVironments**
**Space Data Corporation**

# Cooperative and Coordinated Field Experimentation

**CENETIX**

**OSD/OFT**
**WolfPAC – Stiletto Experiments**

**OSD/OFT**
**HA/DR Project**

**NJ Health**
**Emergency Medical Response Network**

**OSD/HD**
**NPS Maritime Security Program**

**USSOCOM-NPS**
**Cooperative Field Experimentation Program**

- Agile, Adaptive Tactical Networks with Long-Haul Reach-back; Ground, Airborne, Ship, Underwater
- Collaboration Technologies
- Integration with GIG-EF via DREN (CONUS), GIG-BE (theater locations, satellite links), and Abilene (Internet 2 backbone) (overseas clusters)
- Shared Situational Awareness
- Unmanned/Autonomous Vehicles
- Network Controlled UAVs
- Networked Sensors
- Dual-use Technologies for Post-Conflict Reconstruction, Stabilization, HA/DR

**Sites:**

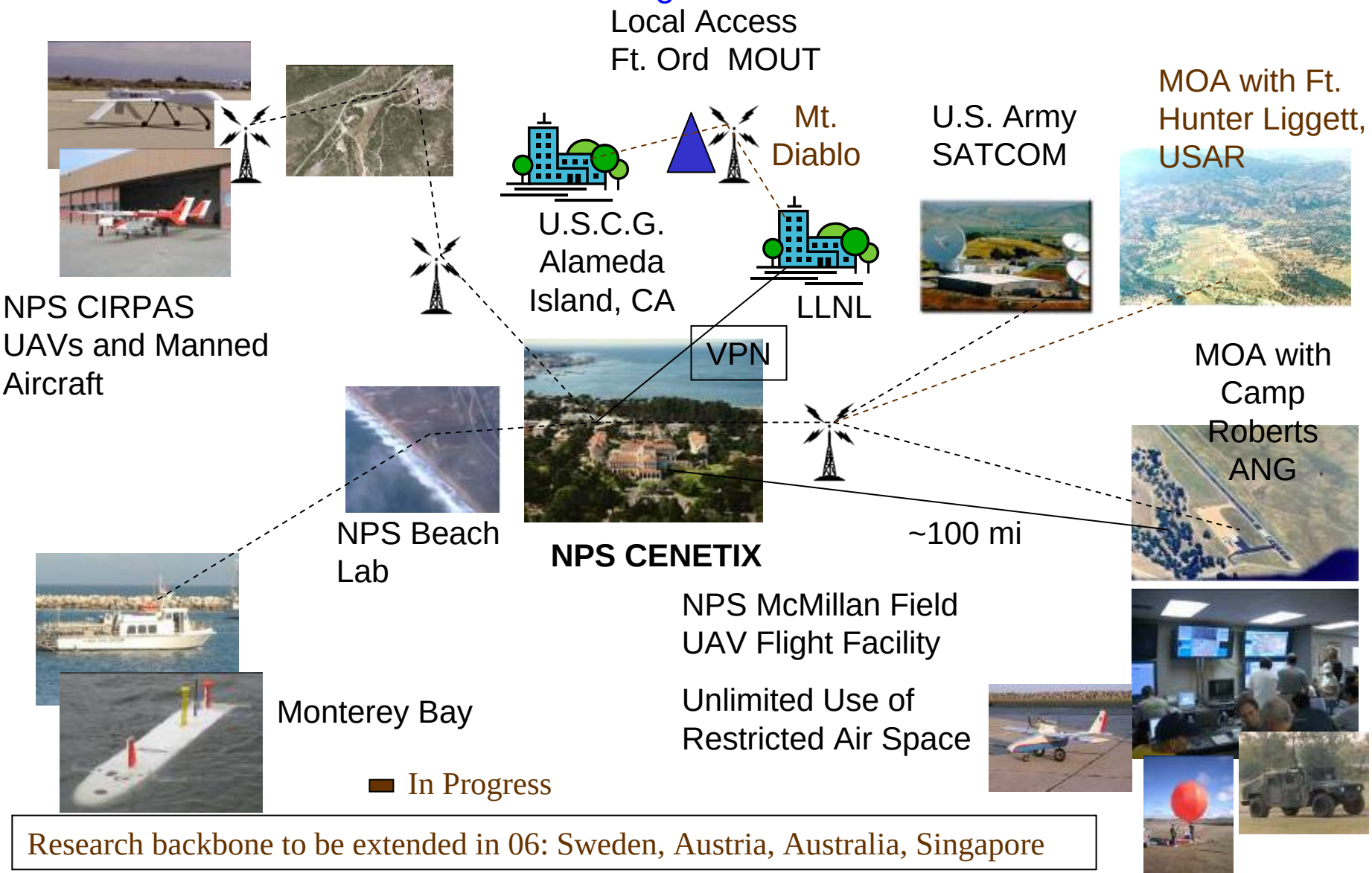
- **Camp Roberts**
- **Ft. Hunter Liggett**
- **Monterey Bay**
- **San Francisco Bay**
- **Avon Park, FL**
- **etc**

- IED Detection and Jamming
- Smart Antennae
- Precision Tracking and Targeting
- Network Vulnerability Assessment
- Red Team Intent
- Human Systems Integration (Warfighters as Users and Evaluators)
- CONOPS

- Modeling and Simulation
- Biometrics
- Airspace Management/Deconfliction
- Data analysis and mining

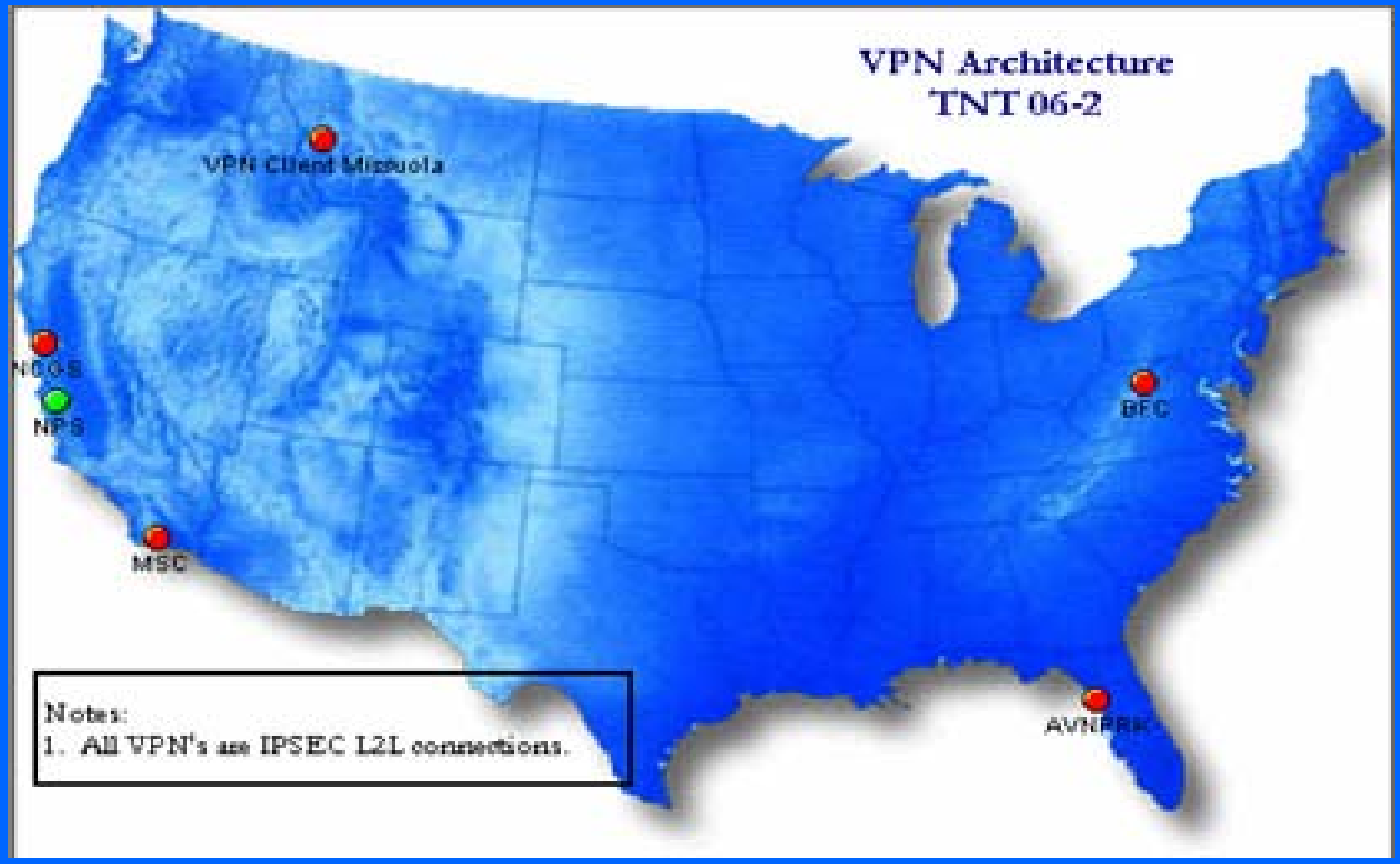
# USSOCOM-NPS
# Cooperative Field Experimentation Program

## Unique Facilities with TNT Plug-and-Play Sensor-Unmanned Vehicle-Decision Maker Networking Testbed with Global Reachback

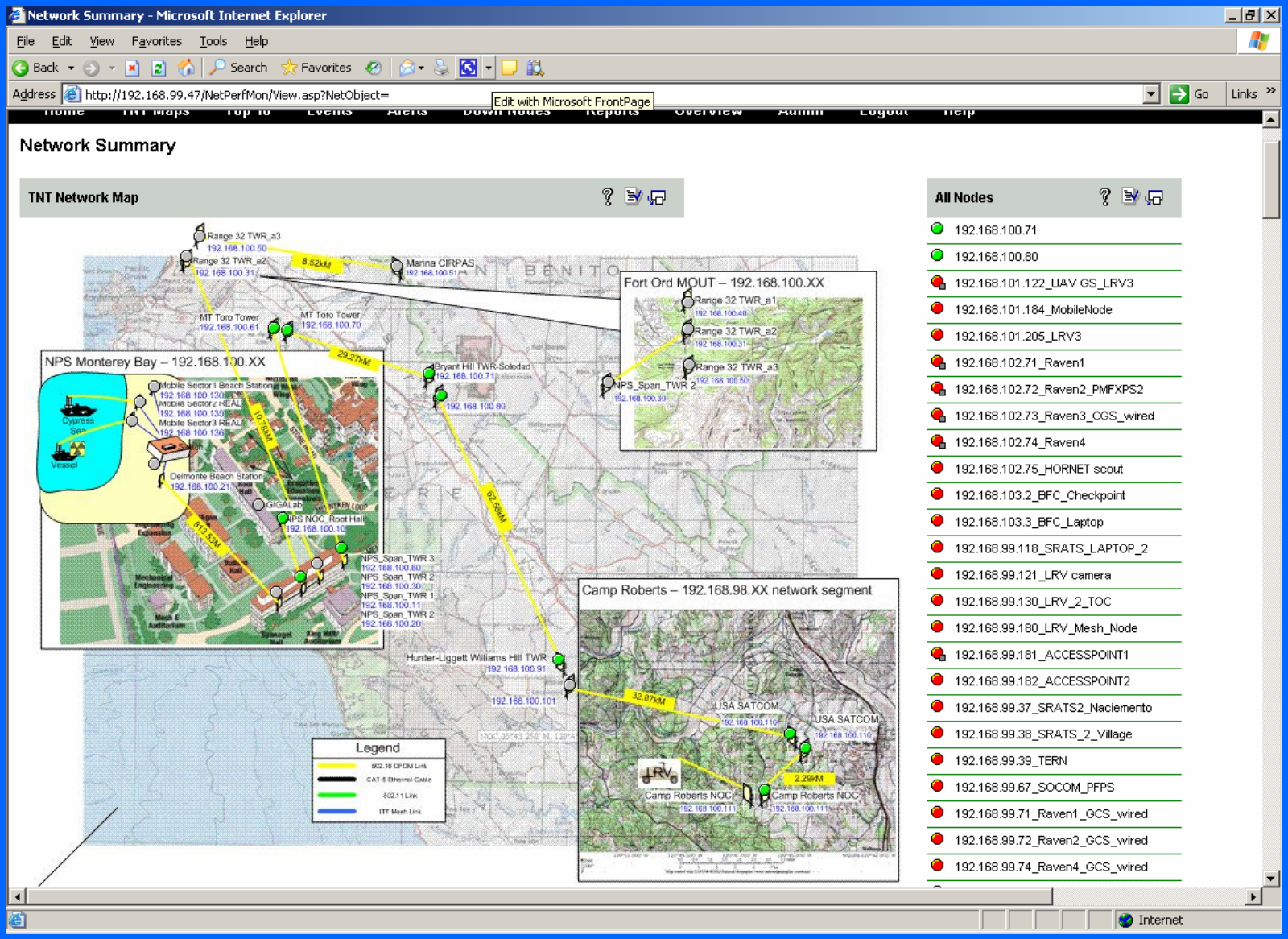



Research backbone to be extended in 06: Sweden, Austria, Australia, Singapore

# Global VPN Reach to the TNT Testbed



# Tactical network testbed with self-forming clusters of small units and unmanned vehicles



# TNT 06-2 Camp Roberts

**Mobile TOCs for Convoys and Checkpoints**

**NPS LRV**

**NGC SRATS**

**SDC Combat SkySAT for Rapid NLOS Comms**

**Raven UAV Image to F-18 for Precision Targeting from Distance**

**Convoy**

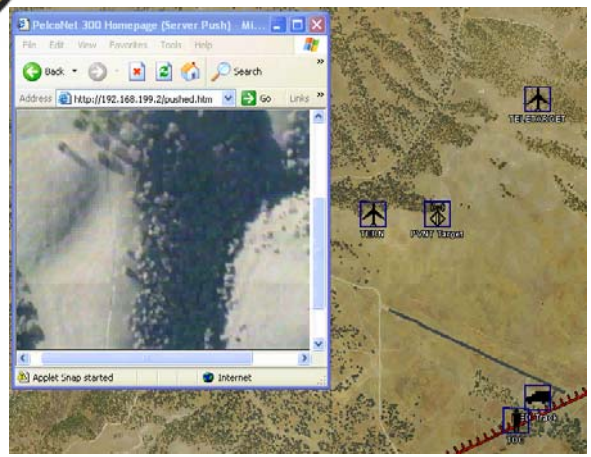
**Biometrics – Disguise Detection**

**TOC**

**MMALV for IED Detection**

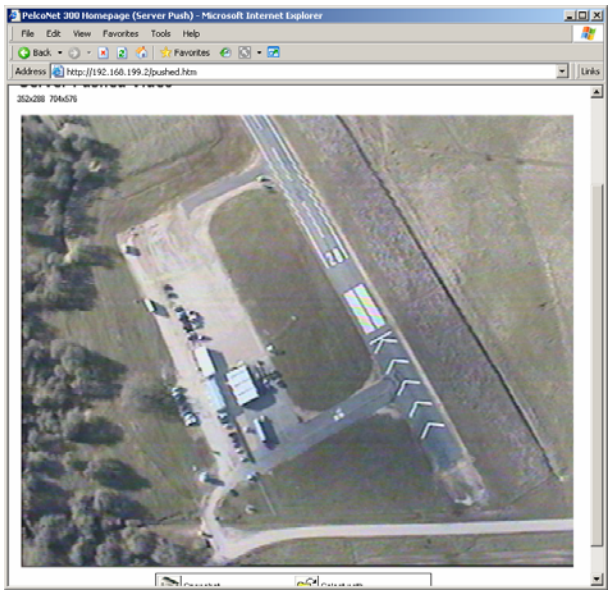
**Under Vehicle with Network Camera**

# TNT 06-2 Camp Roberts

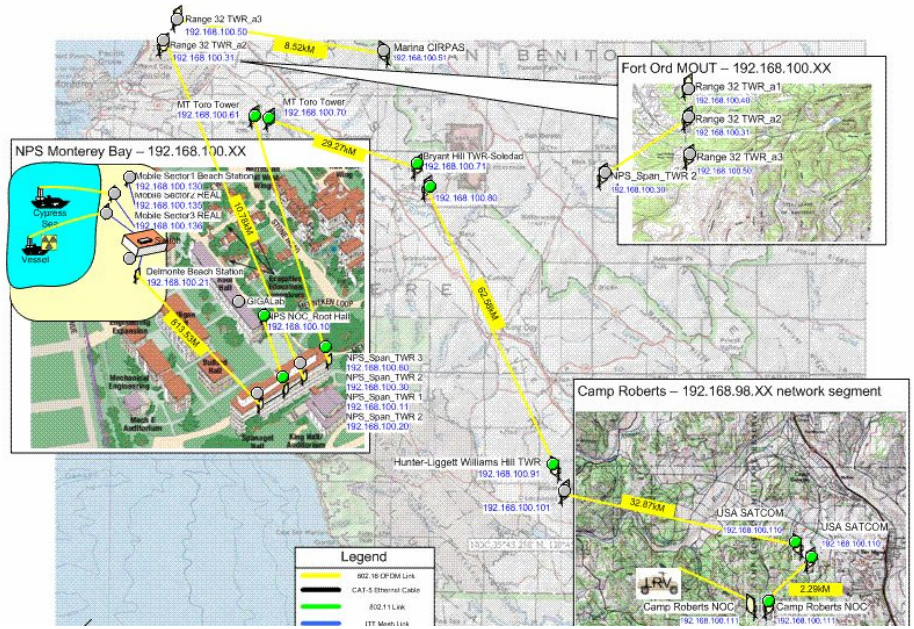



**PFPS integrated with Cursor on Target as NOC SA Agent; Video captured using Cam Studio.**

**Convoy Intercept – Video Application viewed with V-Stream, captured with Cam Studio. Tern video at Camp Roberts viewed in NPS NOC**



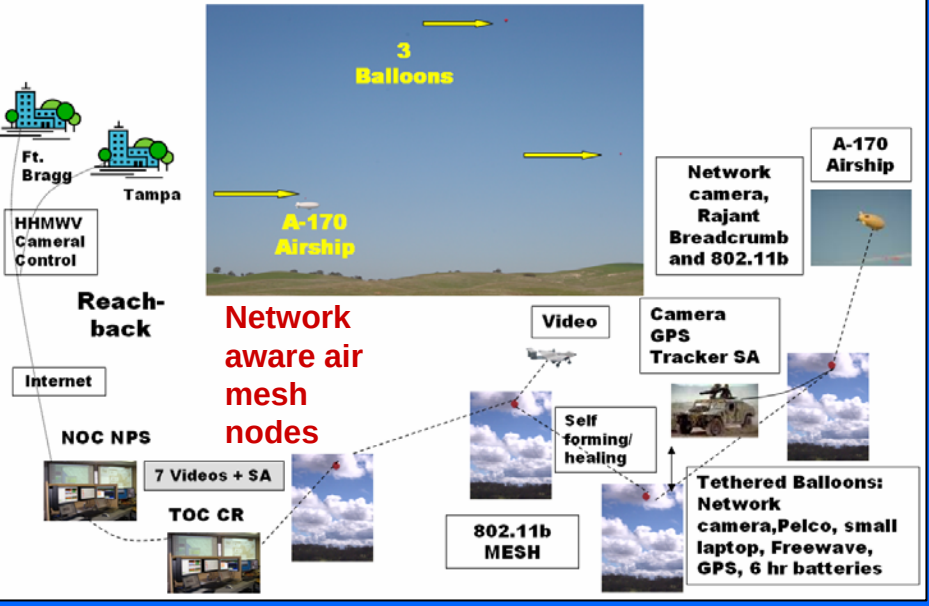

**UAV video at Camp Roberts viewed at NPS NOC**



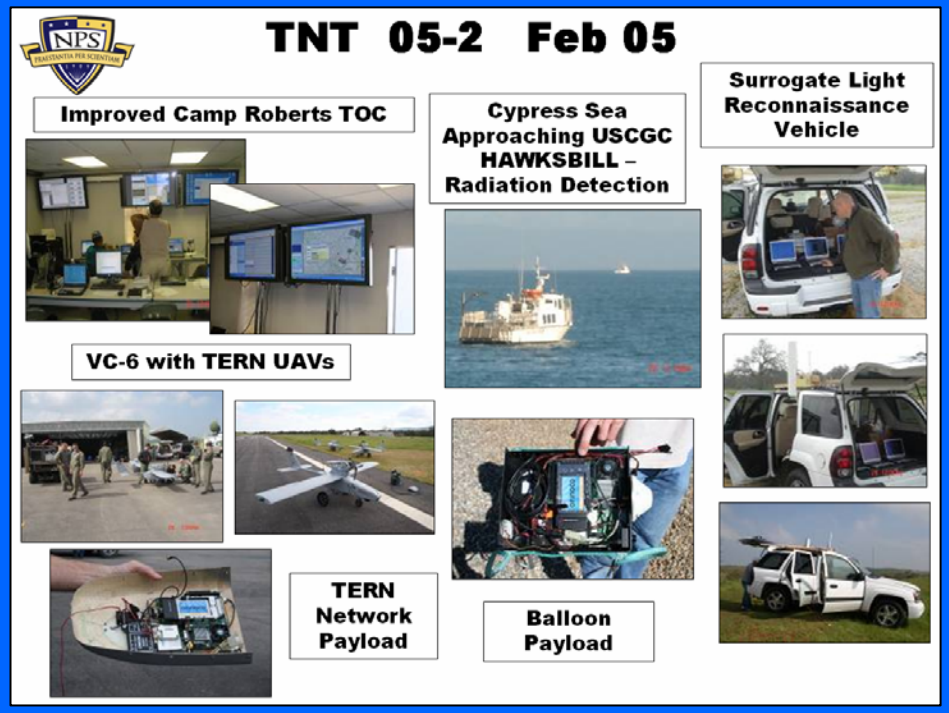

**OFDM Backbone Network Monitoring from NPS NOC**

# TNT 05-1, Nov 2004

## MESH Topology



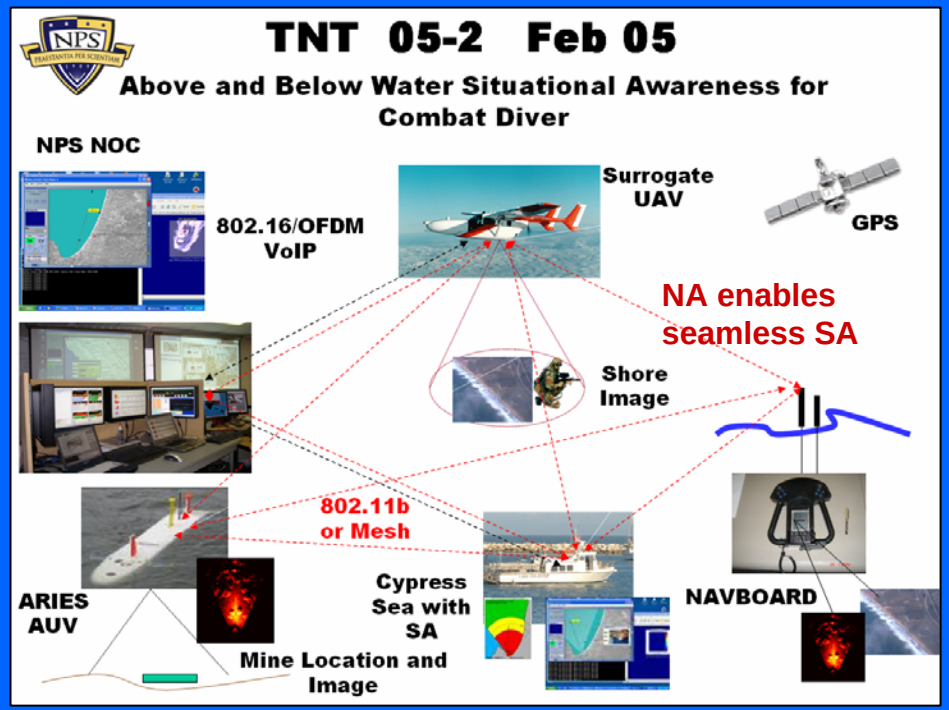

# TNT 05-2 Feb 05




# TNT 05-2 Feb 05

# TNT 05-2 Feb 05

## Above and Below Water Situational Awareness for Combat Diver



# Background MIO Studies: Rapidly Deployable Self-Forming Network for Maritime Interdiction Operations

# TNT 06-1 MIO Network Topology: Forming the Boarding Party network to the target ship

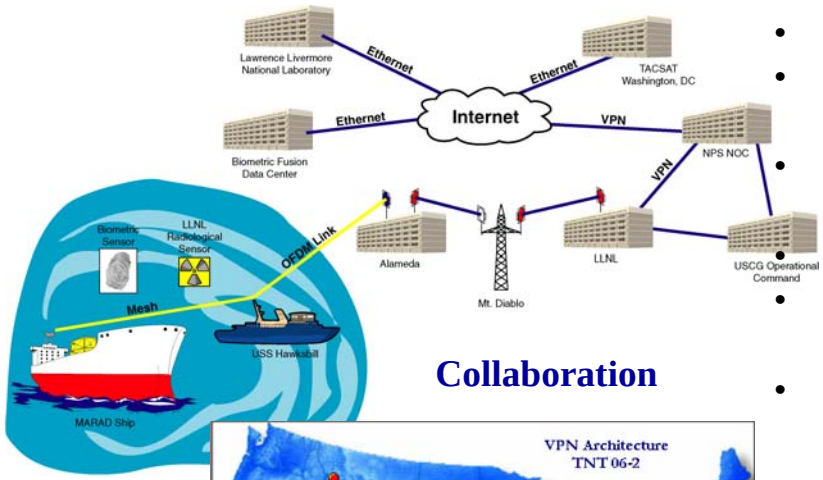
# TNT 06-2 San Francisco Bay

View from Target Ship

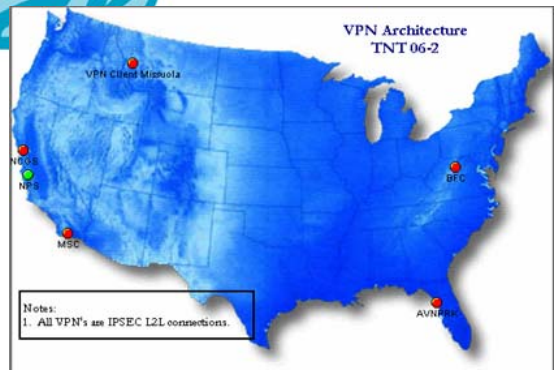
Boarding Party Collaboration with Remote Sites

Rapid 802.16 Network Deployment

- Wireless Network Technologies
- Agile, Adaptive Networks
- Ship-to-Shore links for exfiltration of data to reach-back centers (802.16, 802.20, VPN-Internet/Satellite)
- Ship self-forming network based on ITT mesh solution
- Robust comms at 1.5-4km
- Ultra-wide band communication from within vessel or structure
- Iridium burst mode communication systems (backup)




Collaboration



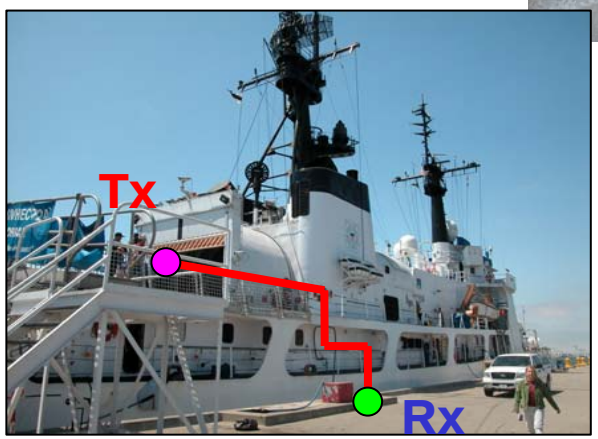
Boarding Party Transit

# Background: Prior NPS-LLNL experiments focused sending data and video in real time within a boarded ship to external networks

Feb 05 TNT: 802.11B affected by radar

May, August 05 TNT UWB comms demonstrated within Cutter

Suisun Bay: UWB able to transmit between holds of a container ship with holds closed!

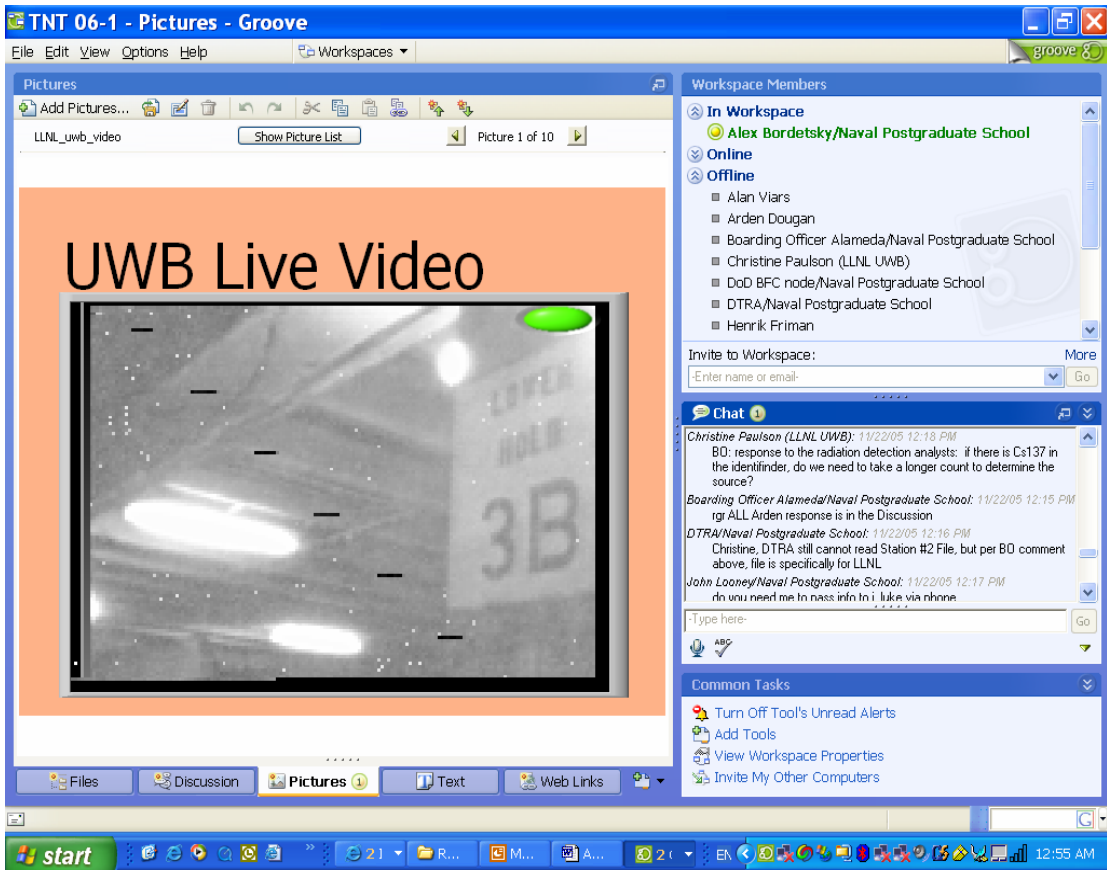



UWB on board USCGC Munro (multi-deck, no radar)

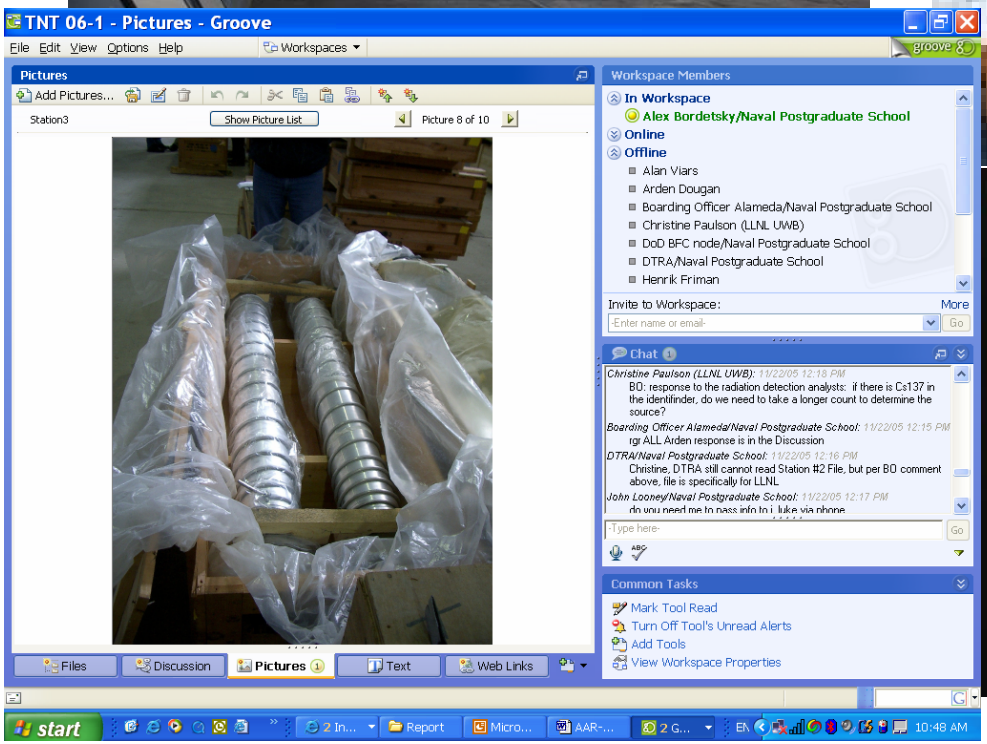
Collected system performance data on operational ship (Point Sur) UWB WORKED in difficult high multipath environment

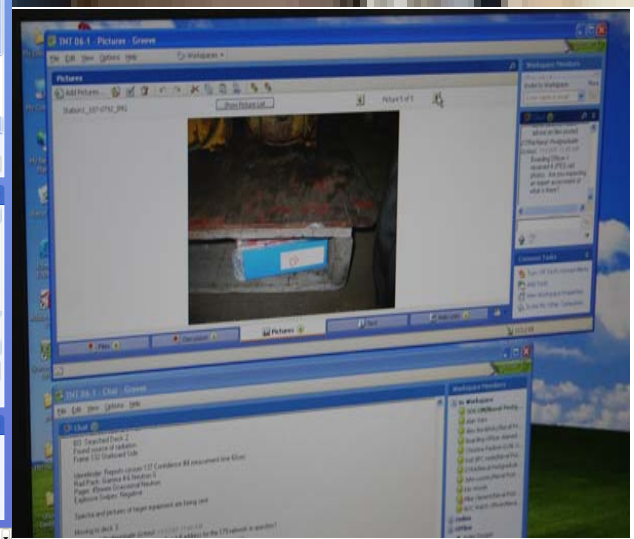
Polar Star – Planned experiment w/ USCG R&D Center

# Sharing UWB Video with DTRA via Groove

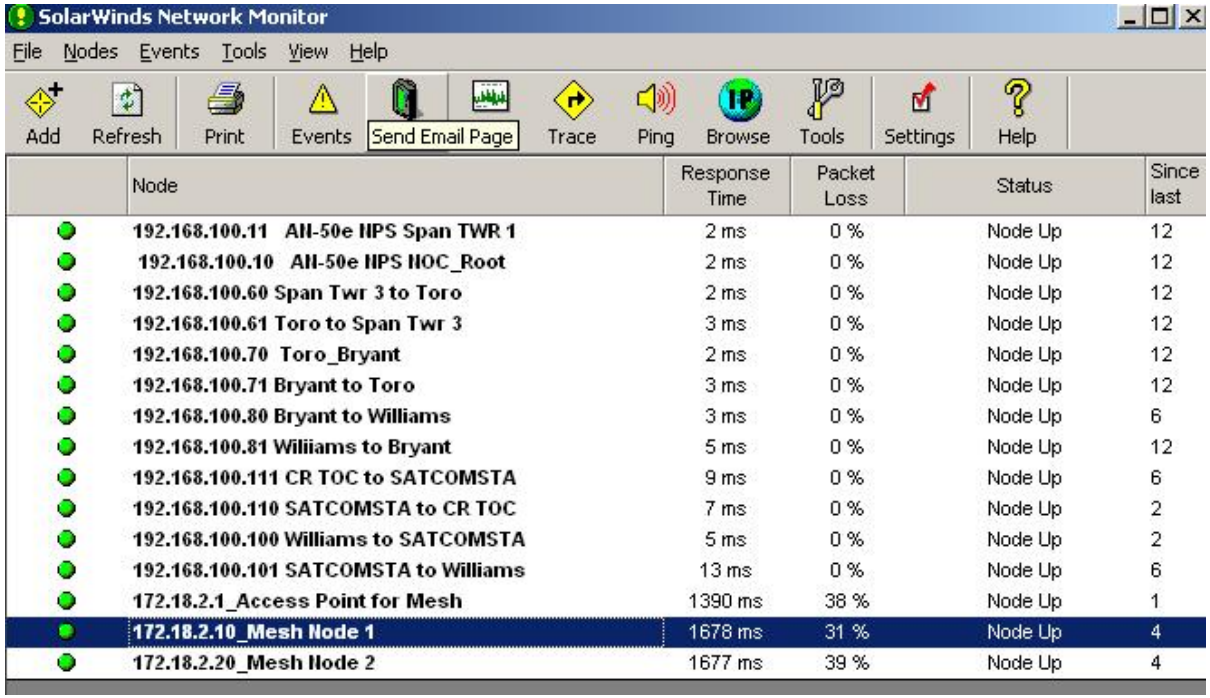


# Boarding Party Self-Synchronization with TOC and DTRA in Groove



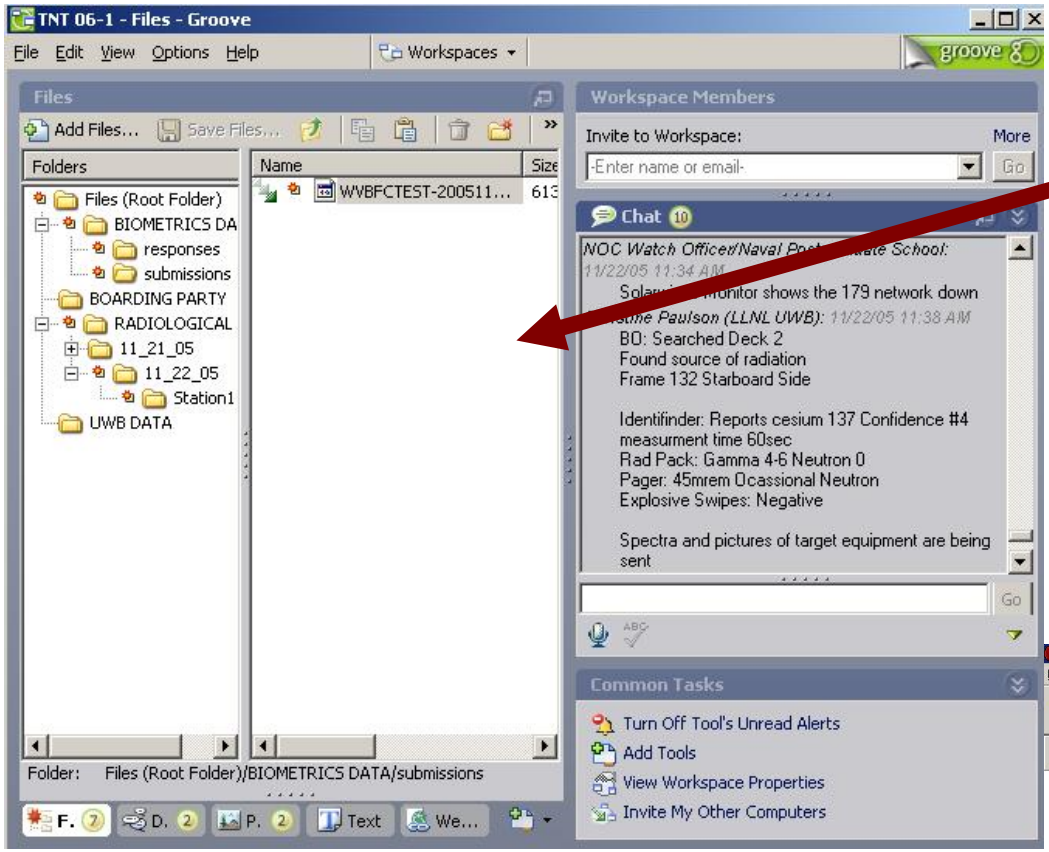
# TNT 06-1 MIO: Testbed in Action, Performance Management at NPS NOC




| Node | Response Time | Packet Loss | Status | Since last |
|---|---|---|---|---|
| 192.168.100.11 AN-50e NPS Span TWR 1 | 2 ms | 0 % | Node Up | 12 |
| 192.168.100.10 AN-50e NPS NOC_Root | 2 ms | 0 % | Node Up | 12 |
| 192.168.100.60 Span Twr 3 to Toro | 2 ms | 0 % | Node Up | 12 |
| 192.168.100.61 Toro to Span Twr 3 | 3 ms | 0 % | Node Up | 12 |
| 192.168.100.70 Toro_Bryant | 2 ms | 0 % | Node Up | 12 |
| 192.168.100.71 Bryant to Toro | 3 ms | 0 % | Node Up | 12 |
| 192.168.100.80 Bryant to Williams | 3 ms | 0 % | Node Up | 6 |
| 192.168.100.81 Wiliiams to Bryant | 5 ms | 0 % | Node Up | 12 |
| 192.168.100.111 CR TOC to SATCOMSTA | 9 ms | 0 % | Node Up | 6 |
| 192.168.100.110 SATCOMSTA to CR TOC | 7 ms | 0 % | Node Up | 2 |
| 192.168.100.100 Williams to SATCOMSTA | 5 ms | 0 % | Node Up | 2 |
| 192.168.100.101 SATCOMSTA to Williams | 13 ms | 0 % | Node Up | 6 |
| 172.18.2.1_Access Point for Mesh | 1390 ms | 38 % | Node Up | 1 |
| 172.18.2.10_Mesh Node 1 | 1678 ms | 31 % | Node Up | 4 |
| 172.18.2.20_Mesh Node 2 | 1677 ms | 39 % | Node Up | 4 |

- **172.18.2.1, Access point for Mesh**
- **172.18.2.10, Boarding laptop, Mesh node-1**
- **172.18.2.20, Boarding laptop, Mesh node-2**
- **172.80.2.40, Biometrics**
- **172.18.1.130, Dr Bordetsky's laptop**

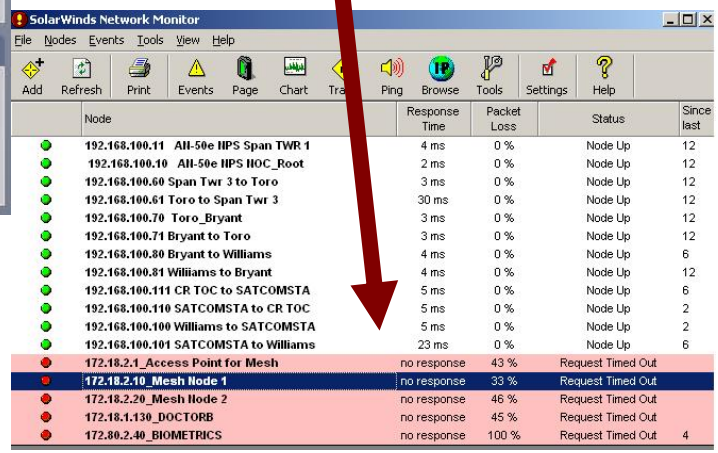
# Performance Management & Collaboration Environment




GROOVE:
Common Operation Picture

NETWORK MONITOR:

Nodes shown down



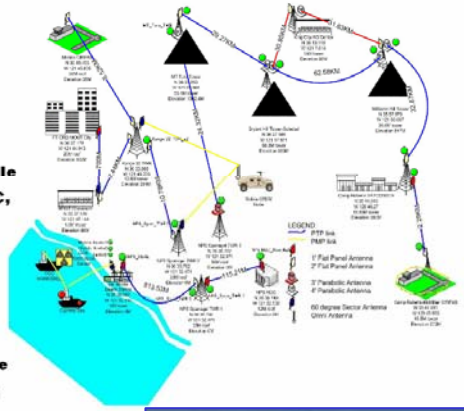
**Lessons learned about adaptive management of self-forming tactical networks:**

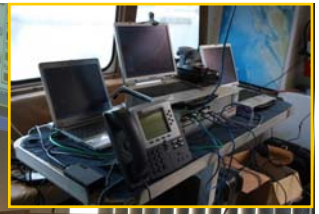
**need to introduce a set of network operation centers cooperatively providing feedback to the mobile nodes**

# TNT Wireless Tactical Network Testbed and NOCs

- CENETIX manages the TNT wireless backbone together with two, student-operated Tactical Network Operation Centers (NOCs), one at the GIGA Lab and the other at the CIRPAS McMillan Field facilities at Camp Roberts. The NOC infrastructure in CENETIX will soon get several additions, including Light Reconnaissance Vehicle based mobile NOC, Coast Guard Ship based NOC, Man-Pack NOC, and other advanced adaptive network operation elements.

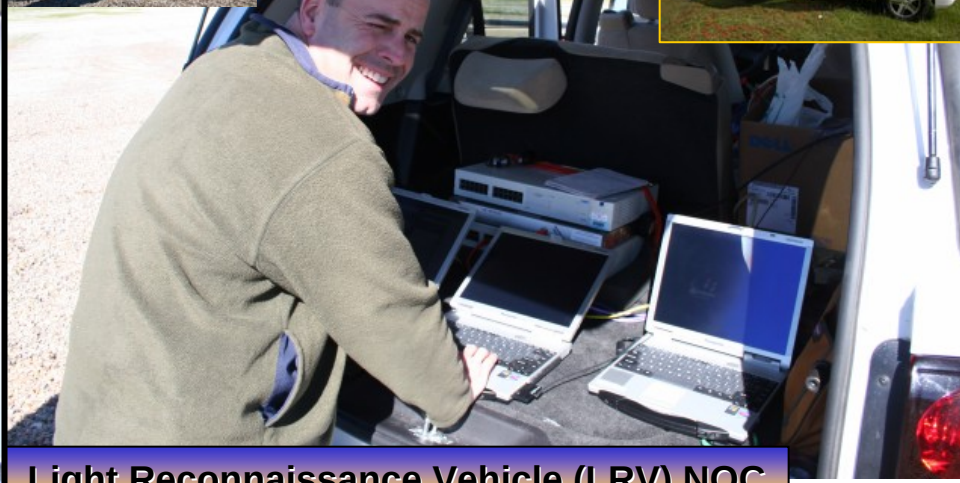
- In addition the new Center will operate as an a applied research site for Homeland Security Projects such as the Emergency and Surveillance Network-Centric Habitats for Homeland Security and a Joint Operations Center together with Command and Control Infrastructure for New Jersey Health Emergency Network.





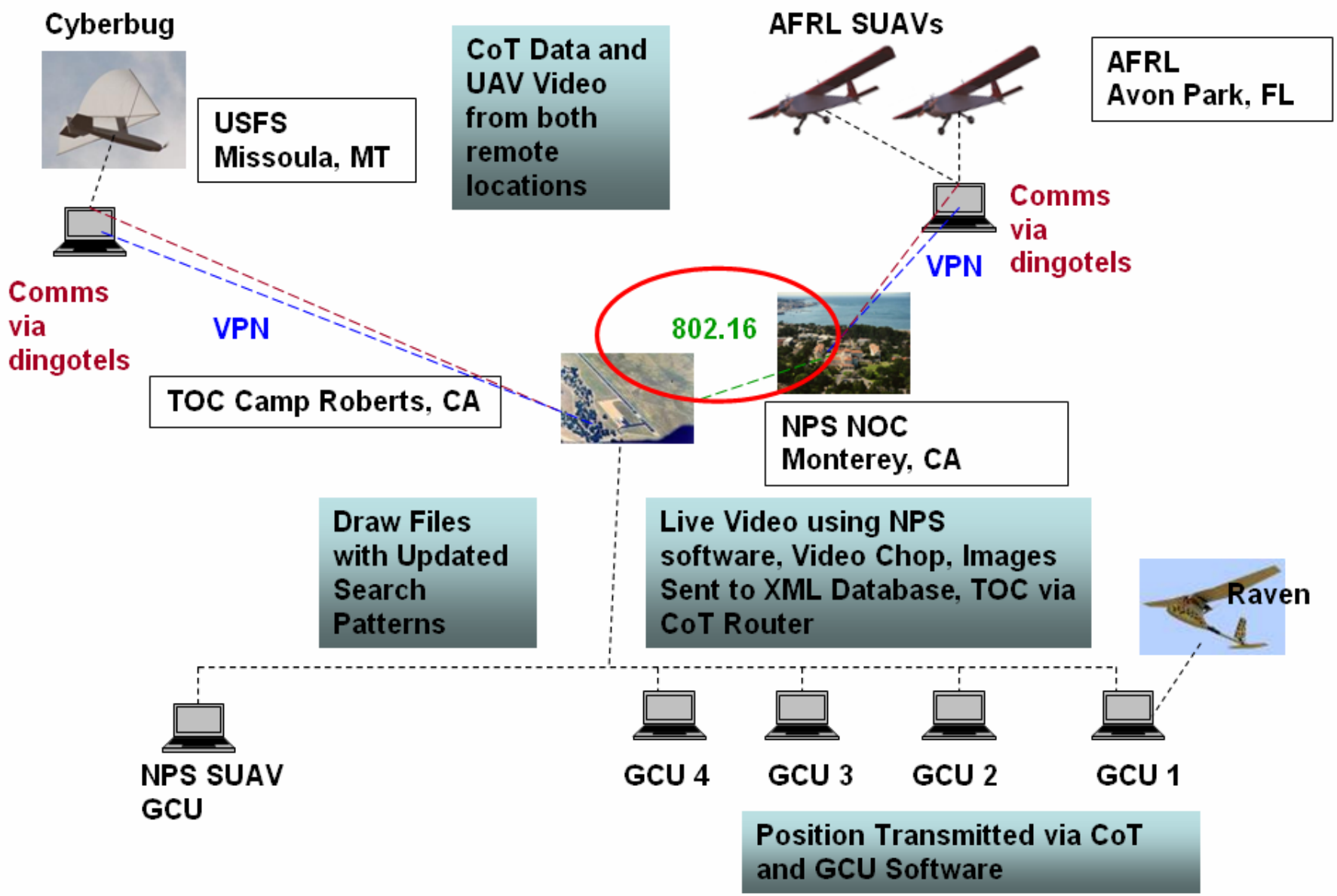
CENETIX GIGA-Lab (NOC)

Deployed NOC (DNOC) Camp Roberts



Light Reconnaissance Vehicle (LRV) NOC

# TNT 06-2 Experiment 5
# Shared SA and Search Pattern Updates

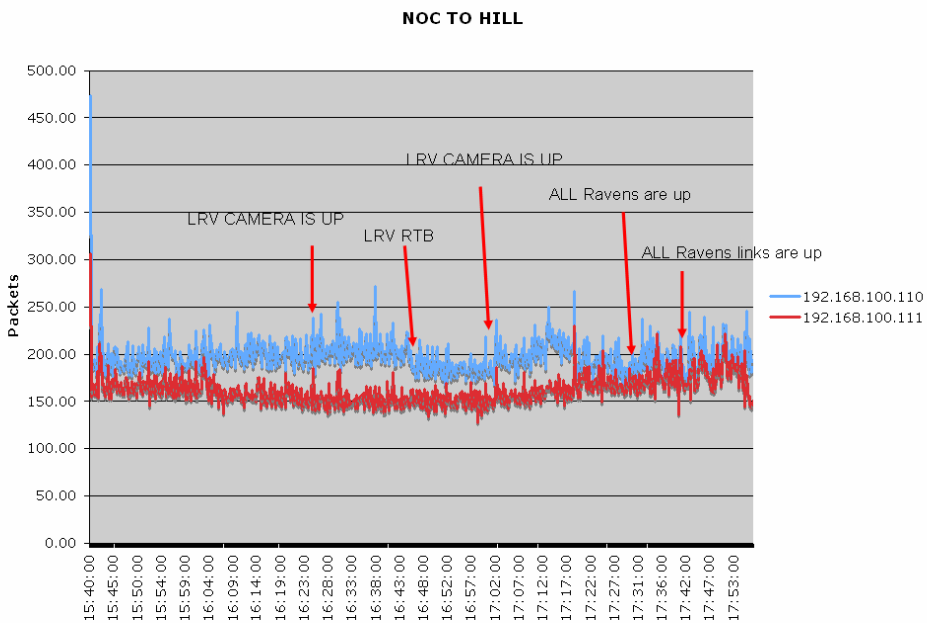


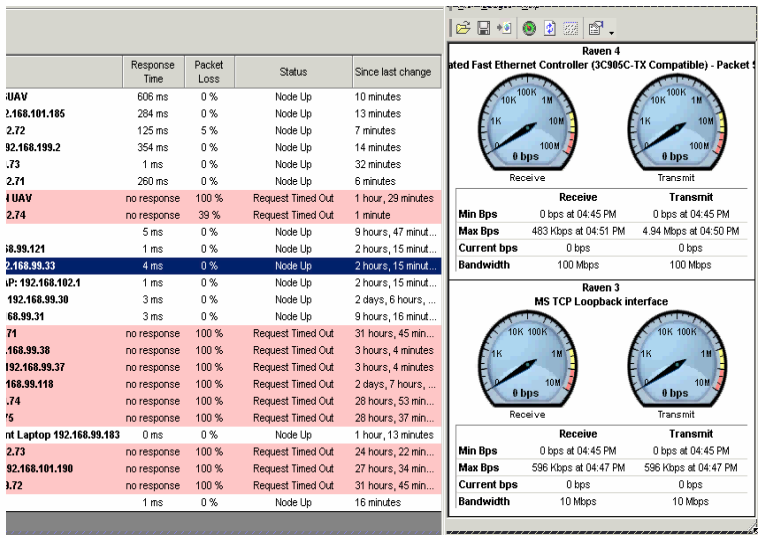
# Four HVT UAVs are streaming video, one video flow is lost, NOC feedback is needed immediately

# NOC Response

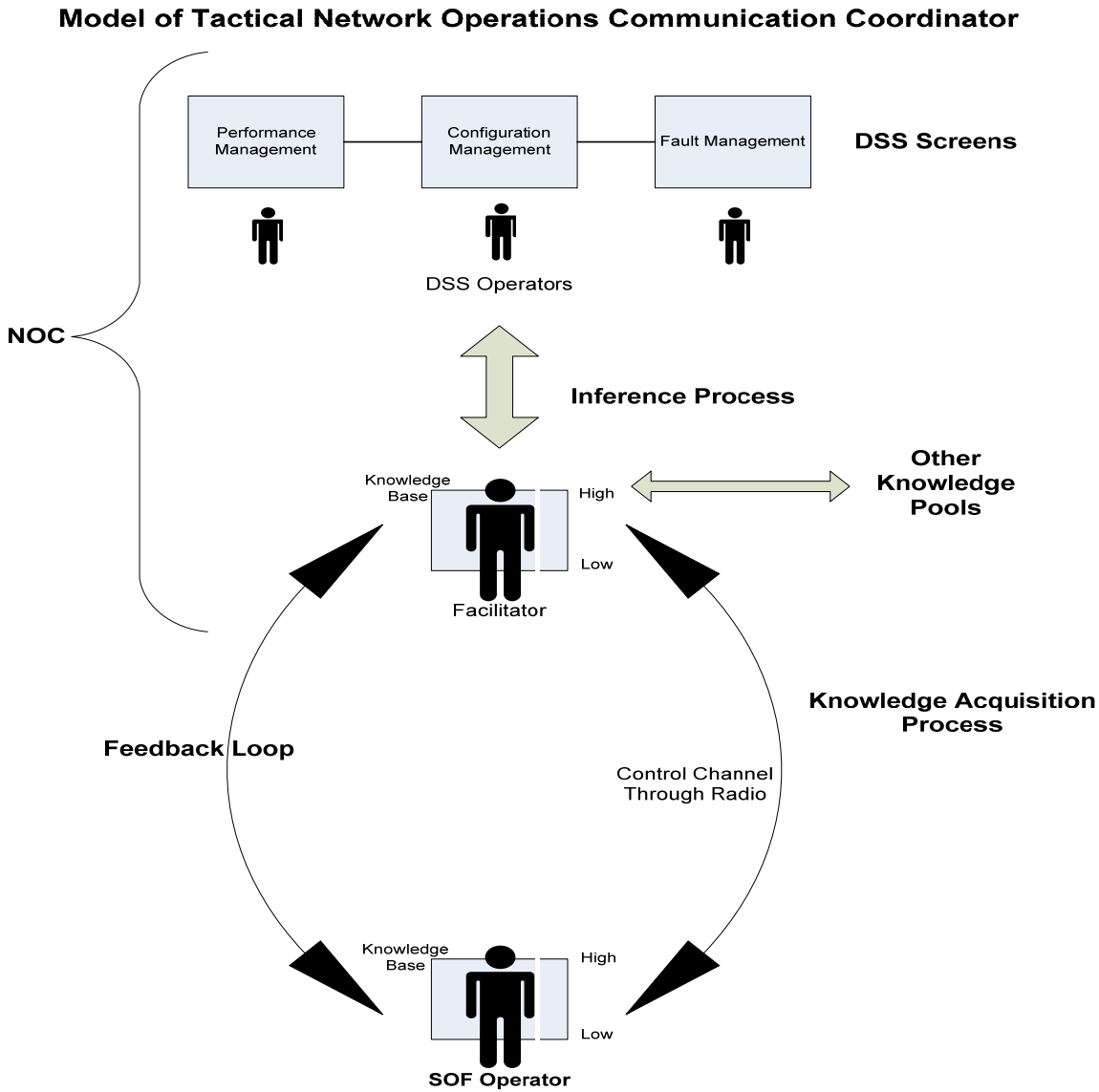
View of the tactical wireless OFDM 802.16 link behavior

View of Performance and Fault Management Monitors



# NOC Adaptive Management Model: Facilitator/Coordinator Feedback Loop

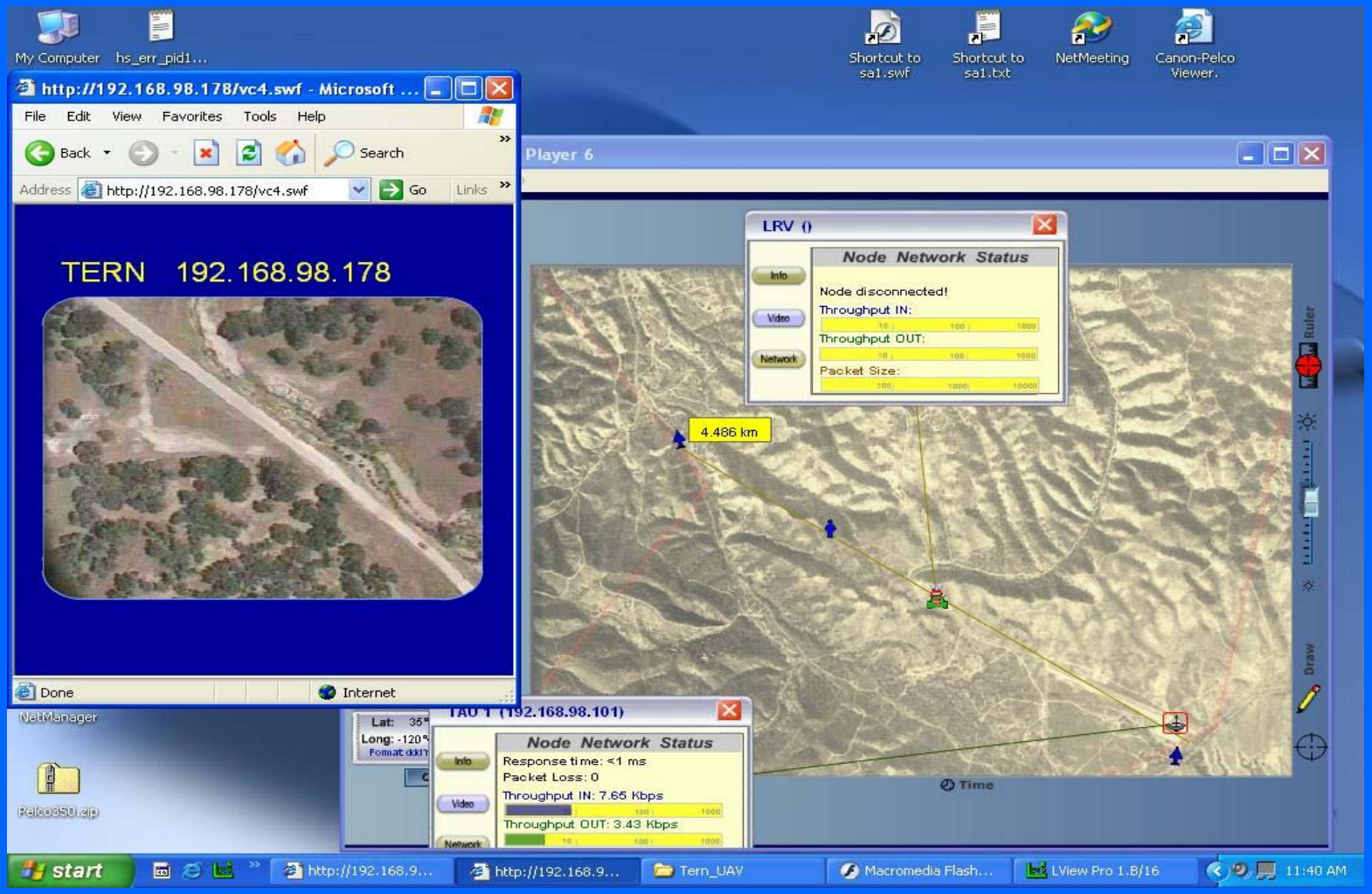


# Hyper-Nodes:

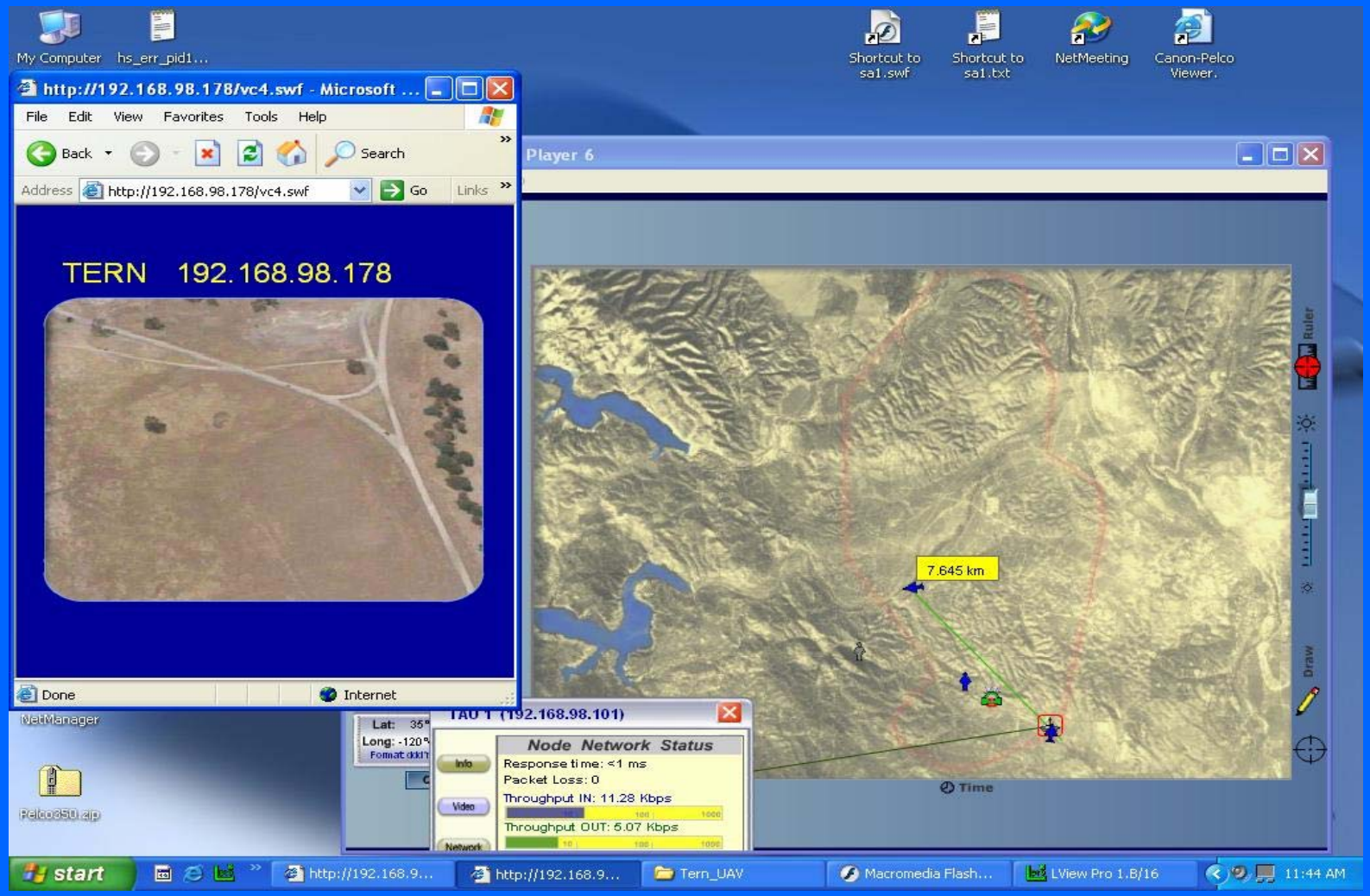
## Transferring NOC functionality and feedback control to network-aware and network operations capable nodes

The hyper-node would short-cut NOC feedback loop by adding to the top of the OSI reference model the 8th layer with simplified NOC functionality onto the hyper-node protocol stack.

# Network-aware nodes in UAV-based HVT operations: mapping SNMP data into the SA view

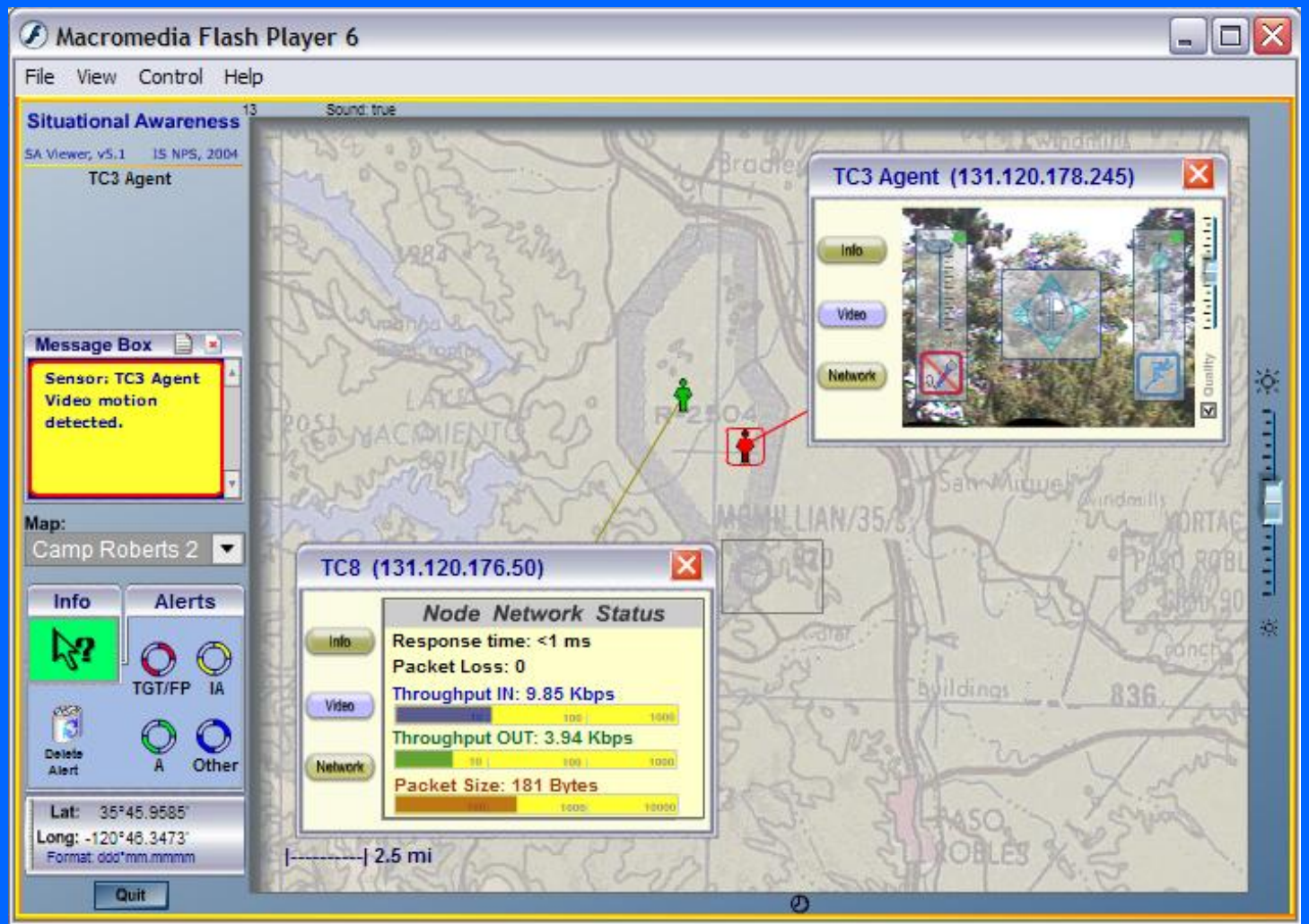


# Network aware UAV operator (SNMP-SA gauge) shortcuts LRV, extending the air link directly to next UAV. The longer air link results in the lower video quality



# TNT 05-2, Feb 2005

Video Sensor is aware of SOF operator networking P2P status, i.e. capability to transfer video through his networking gear



# Looking inside the building via the UAV: UWB solution

# 8th Layer Architecture

- Dr. Sarah Stein, North Carolina State University, in her paper on 8th Layer Initiative writes: "There are seven layers in the networking architecture that define how systems communicate. This architecture is the foundation on which all information technology (IT) is built. Insiders frequently refer to the human factor in IT as the eighth layer. The title is the message; our greatest challenge is not the technology." (Stein, 2004, p. 3)
- With a different focus, Russel Ormond, presents the concept of Layer 8, which he tags as financial, and Layer 9, referred to as political, extensions to the OSI stack (Ormond, 2004)
- Bauer and Patrick directly refer to the new layers as human factor extension to the OSI seven layers (Bauer and Patrick, 2004)

***In this paper we argue that mapping NOC capabilities in Layer 8 functionality is critical for emerging Command and Control network-centric environments based on unmanned vehicle-decision maker adaptive self-forming networks. Ideally, we'd like to have the 8th layer mapping the network management hierarchy of services in a way similar to TMN (Telecommunications Management Network) network management architecture***

# TMN Model: The 8th layer protocol would provide individual nodes with the capabilities of self-diagnosis (NEL), subnetwork view (NEML), end-to-end performance (NML), QoS requirements response (SML), and Service Level Agreements negotiation (BML)

| | |
|---|---|
| BML<br>Business Management Layer | Enterprise Management: agreements between operators, planning, configuration management, executive actions |
| SML<br>Service Management Layer | Service Management:maintaining QoS, sevice provisioning, service transactions, service creation |
| NML<br>Network Management Layer | Intelligent network Operations Support (OSs):end-to-end view of TN, global views within NEML domains, summaries |
| NEML<br>Network Element Management Layer | Intelligent Subnetwork Controllers (SNEs): subnetwork view, distributed NE s management, distributed data screening, root cause analysis |
| NEL<br>Network Element Layer | Intelligent NEs: performance data collection, alrm collection, self-diagnostics, address translation, root cause analysis, data screening |

# The 8th Layer Monitors

In accordance with TMN architecture we can describe the event-constraint space of a typical NOC by the following categories:

- -NEL, NEML, and NML events and constraints, primarily captured by means of the SNMP protocol
- -SML, primarily reflected in the situational awareness interface requirements (video of certain quality, shared files, response time, distance to the node, etc)
- -BML, primarily reflected in SLA negotiation (availability, reliable connectivity) events.

Correspondingly the hyper-node 8th layer should include several Monitors with the associated polling and event interpretation protocols:

- -SNMP events Monitor (OSI layers 2-4, TMN NEL, NEML, NML),
- -SA constraints Monitor (TMN SML),
- -SLA constraints Monitor (TMN BML).

# 8th Layer SNMP events Monitor:

Extending the SNMP MIBs (Management Information Basis) to the new layer of service and business management variables, including the facilitator decision space:

- Application switching,
- Node physical mobility initiation,
- Receiver Context and Requirements Modeling,
- Sender Dynamic Information Context and Transmission Requirements Modeling,
- Recipient context determination,
- SLA generation,
- SLA negotiation,
- QoS monitoring and SLA assurance, etc.

# SA Constraints Monitor: Cursor-on-Target Approach

What, When, Where, and Details commands with broad range of requirements

to the situational awareness application flow (CoT Overview, 2005):

What: *Tasking*

When: *Task Validity Period*

Where: *Search Location*

Details: *Target Description*

What: *Chat*

When: *Now*

Where: *Everywhere*

Details: *Message Text*

- -Tactical Imagery (Raider, Adocs, IPL)
- -Real-time ground blue force positions (FBCB2)
- -Weapon target pairing solutions (DLARS)
- -Real-time tactical air picture (Link16, CT-II, ACARS)
- -Strike engagement orders (ADOCS, Raider, Link16)
- -ISR collection requests (Raider, AFATDS, DLARS)
- -Weather data (GATM)
- -SIGINT information (SIRS, NCCT, ISRW)
- -Mensurated target locations (DPSS, Gridlock)
- -UAV sensor point of interest (Predator)
- -Platform cross cueing data (Predator, Link16)
- -Air Support Requests (AFATDS)

# SLA constraints Monitor (TMN BML)

The SLA represents a desired level of information the hyper-node believes will help it achieve a maximum result. In terms of such a goal SLA, the principal 8th Level messages include:

- Request for bid for given SLA
- Offer of bid for SLA in response to a request for bid
- Acceptance of offer of bid for SLA
- Confirmation of offer in response to acceptance of offer of bid for SLA
- Report of predicted violation of SLA by the provider
- Offer of revised bid for SLA in response to predicted violation
- Cancellation of SLA by requestor

# 8th Layer Protocol: SA (CoT) Model for Monitors Unified Set of Commands

**SNMP Monitor:**

What: *A request for information of a UAV throughput*
When: *End of SNMP Polling Period*

Where: *UGV Hyper Node, GPS Location*

Who/how: *UGV Hyper Node SNMP Manager, Polling the UAV MIB*
Details: *Sending the SNMP **get** packet via the UDP port*

What: *A request for information on route to Tactical Operation Center node*
When: UAV Ground Station *Situational Awareness Alert*
Where: *UAV Hyper Node, GPS Location*

Who/how: *UAV Hyper Node SNMP Agent, Reading the UAV MIB*
Details: *Sending the SNMP **trap** packet via the UDP port*

**SLA Monitor:**

What: *Request bid for <SLA>*

When: *Task Validity Period*
Where: *From supplier to consumer*
Details: *Dynamic information content, quality, timeliness*

What: *Offer bid for <SLA>*

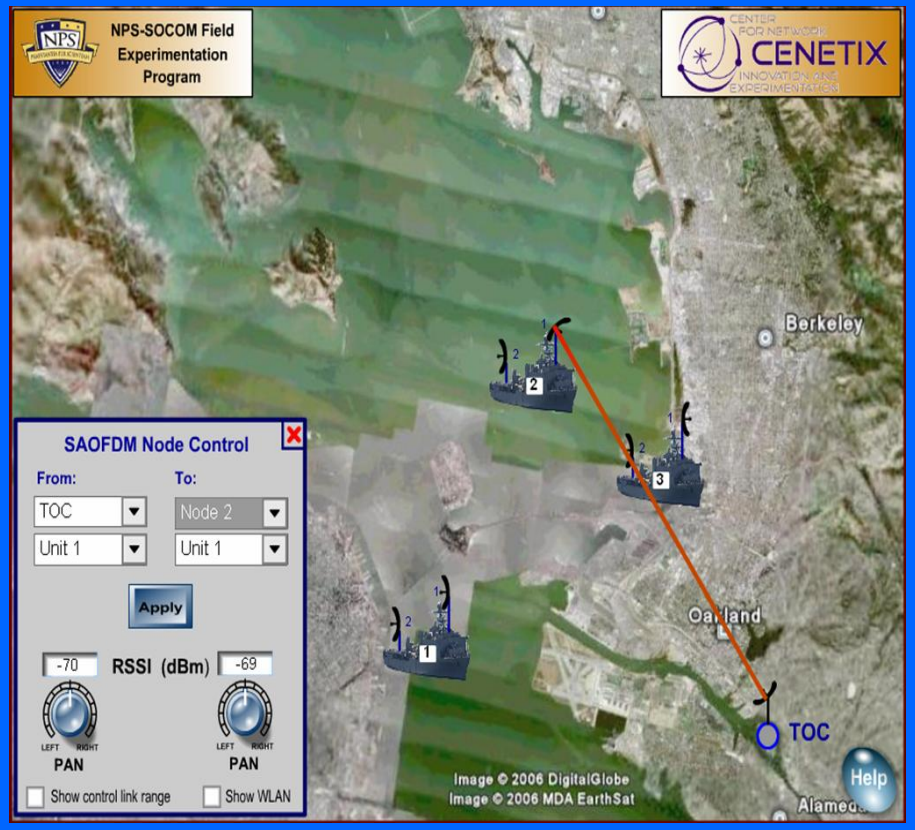
When: *Task Validity Period*
Where: *From supplier to consumer*

Who/how: *Network service provider making bid*
Details: *Dynamic information content, quality, timeliness*

# Example of 8th Layer Concept Application

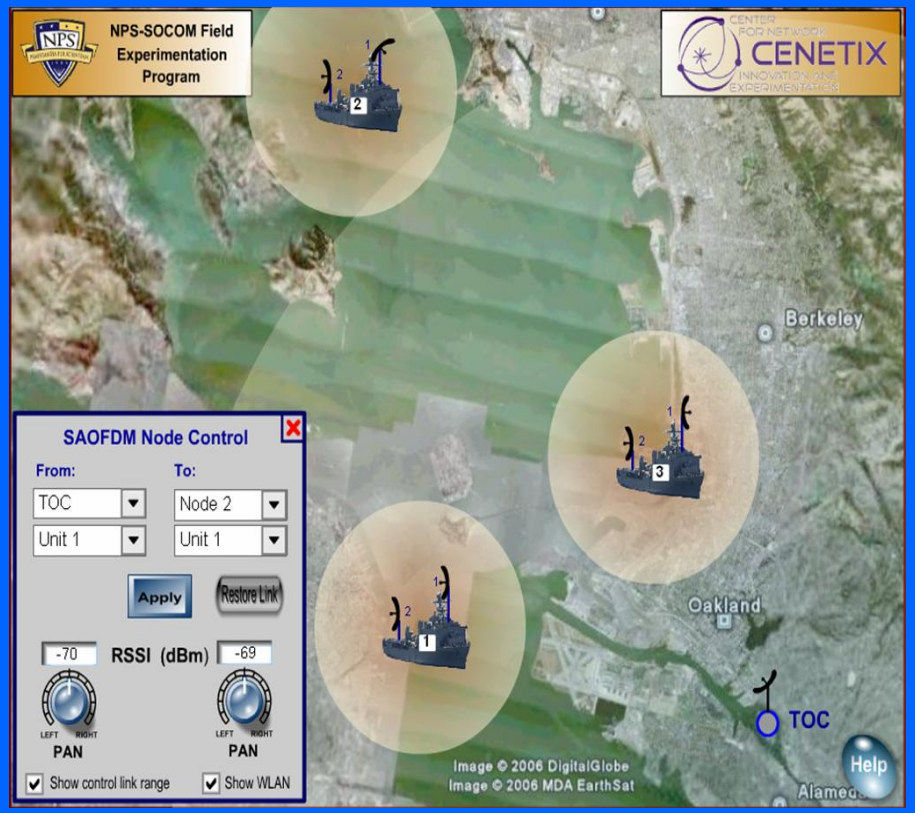
(Demonstration program designed by Eugene Bourakov)

- The Layer 8 process starts at the level of Situational Awareness Interface used by the local commander. TOC SLA monitor requests service from hyper-nodes with Self-Aligning OFDM antennas (SAOFDM)
- The SAOFDM node SLA monitor responds positively by assisting remotely targeting the antenna directly of the Situational Awareness View. The OFDM link is established.
- The SNMP Monitor for SAOFDM node responds by highlighting the red line indicating that link is feasible



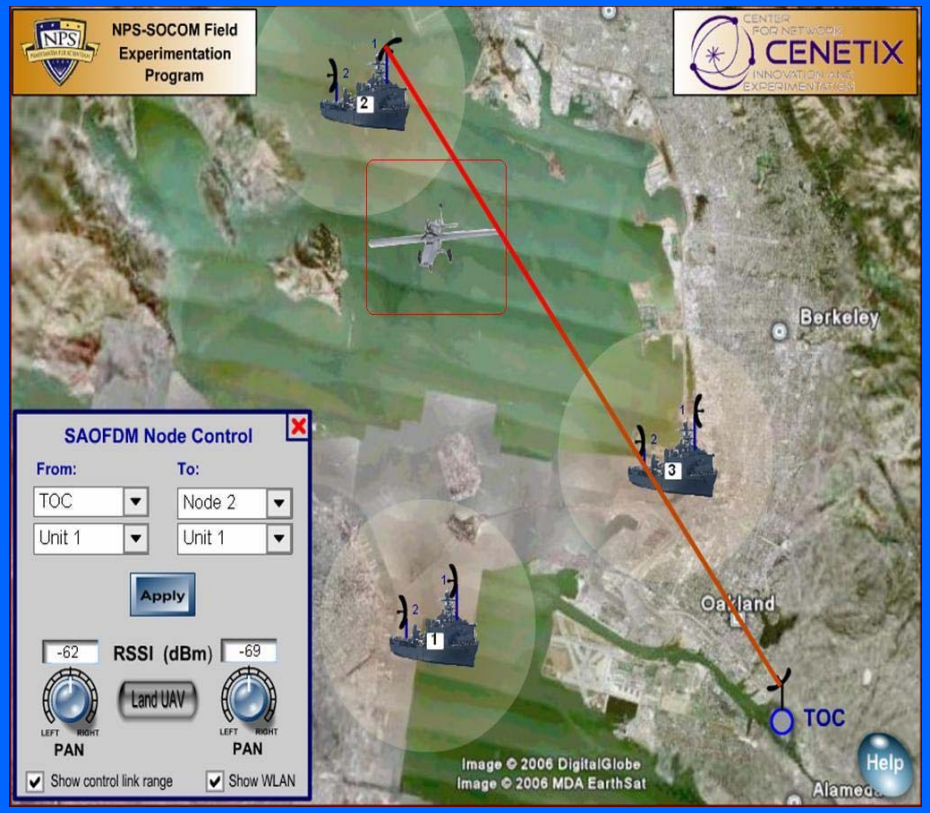
# Layer 8 representation of ship-to-shore service loss (hyper-nodes stretched the self-forming network too far)

- As Ship 2 continues to follow the vessel of interest (SA Monitor report), it's hyper-node (SAOFDM) SNMP Monitor reports that OFDM link breaks down
- The SA View shows it is infeasible, three OFDM WLAN circles don't overlap.



# Layer 8 work on restoring the Ship-to-Shore service by activating UAV relay

- The TOC Commander SLA Monitor request restoring the service to the Ship 2 position reported by SA Monitor:
  - **What:** ***Boarding Party Chat***
  - **When:** ***Now***
  - **Where:** ***Ship 2 position***
  - **Details:** ***Message Text***
- The UAV SLA monitor responds positively, accepting the Way Point to Ship 2 from SA monitor (CoT work)
  - **What:** ***Request bid for <SLA-UAV relay>***
  - **When:** ***4-10 min***
  - **Where:** ***From TOC to Ship2***
  - **Details:** *Enable OFDM link, video, radiation detection files sharing*
- The SNMP Ship 2 Monitor and SNMP UAV Monitor respond that solution is doable by restoring red line in the SA view



# Hyper-Node at Work

SAOFDM_MIO.swf

# Conclusions

- In the paper we presented the vision for a new *8th layer* that extends the well known 7-layer OSI model to implement adaptive networking by giving every critical node of a C4I network its own specialized Network Operation Center (NOC) capability
- We introduced the concept of *hyper-nodes*, which adapt their behavior and organization through incorporation of this 8th layer
- We described a possible architecture of the 8th layer monitors and possible protocol based on the Cursor-on-Target and SLA agreements format
- Next steps of our research include Pareto boundary identification for 8$^{th}$ Layer Monitors as well as format and headers for 8th Layer "packets", which would also reflect on service routing solutions

# Questions?

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