



Sensor-Unmanned Vehicle Networks : Tactical Network Testbed (TNT) Approach

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Compiled of joint presentations with Dr. Dave Netzer, TNT Director



Background: NPS Field Experimentation Program, STAN, and TNT Experiments

OBJECTIVES:

- Provide opportunity for **NPS students and faculty to demonstrate and evaluate their latest technologies in an operational environment** and provide operational community the opportunity to utilize and experiment with these technologies.
- **Take advantage of operational experience of NPS students.**
- Provide Military and National Laboratories, DoD Contractors, and other universities opportunity to test and evaluate latest S&T in operational environment; **small, focused field experiments with well-defined measures of performance.**

HISTORY:

- **Began in FY02** – use of UAVs for improved capability of downed pilot rescue
- **Jan. 03** - combined field experimentation program with CW2 Chris Manuel's Surveillance and Target Acquisition Network Project (STAN) – quarterly field experiments began **July 03**
- **FY05 STAN transitioned to USSOCOM programs MAI and JTCITS and NPS TNT (Tactical Network Topology)**

PRIMARY SUPPORT:

- **CDTEMS (Congressional Funding): FY03 = \$1M, FY04=\$2M, FY05=\$1.75M**
- **USSOCOM: FY05 = \$1.96M (Light Reconnaissance Vehicle), FY06 (JMUST)**



Availability Facilities



NPS/
CIRPAS

MOUT,
Old Ft. Ord



NPS Campus



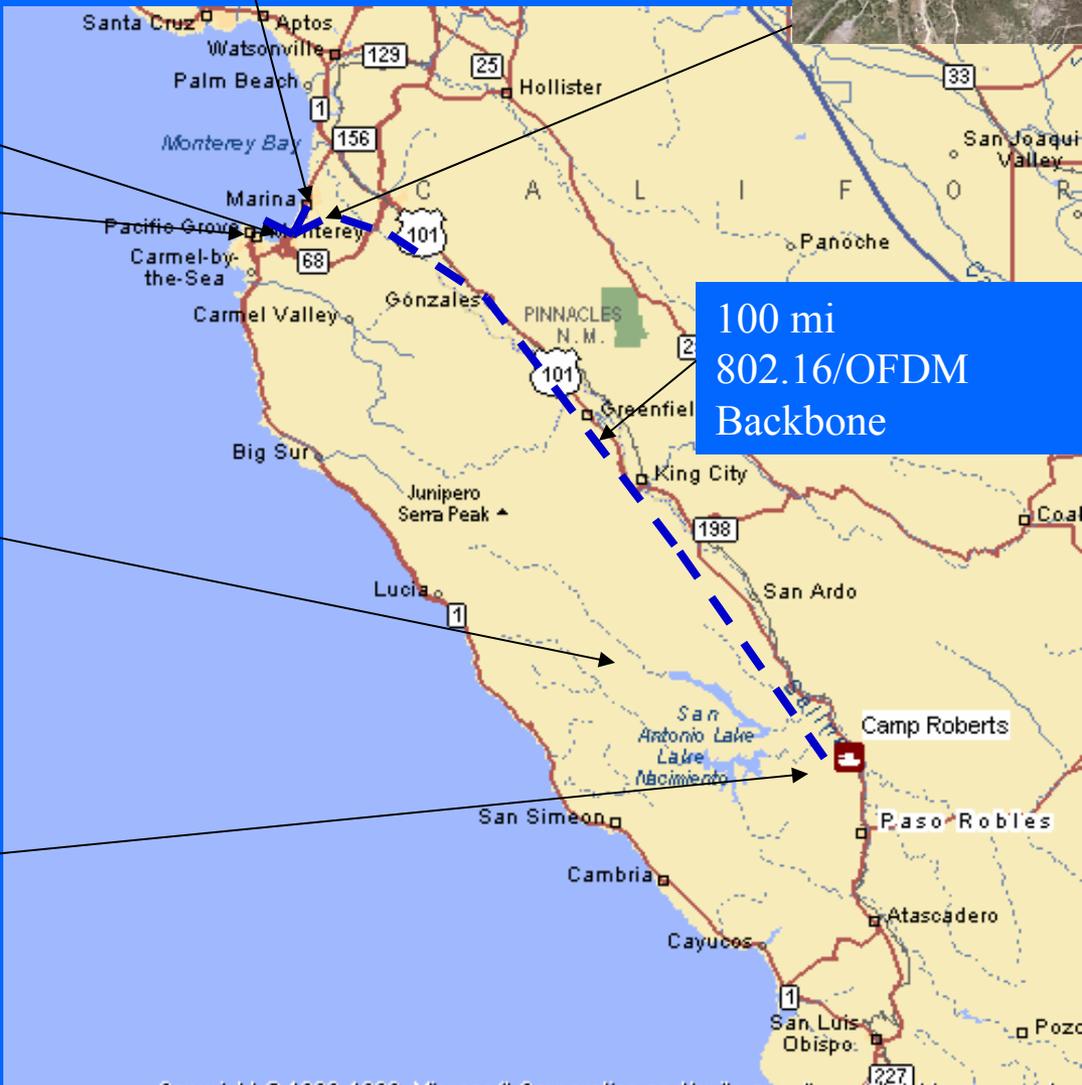
Beach Laboratory
and Monterey Bay



Ft. Hunter Liggett
165,500 Acres



Camp Roberts
42,784 Acres



100 mi
802.16/OFDM
Backbone



NPS Air Assets

CIRPAS



GCS
(2)



Predator (2)



GNAT 750 (2)



Altus ST



Pelican Surrogate UAV (2)



AN/MPQ-64 Sentinel Air
Surveillance and Target
Acquisition/Tracking Radar



UV 18-A Twin Otter



TERN and FROG (3)
(Plus multiple TERNS provided
by SOCOM – flown by VC-6)



Tethered Balloons



Small and Micro UAVs



FY05 TNT Team

NPS:	- FY 04: 23 Thesis Students, 22 Faculty - FY05: 22 Thesis Students, 31 Faculty (to date) Course Projects: IS, OR, CS
Students	- Joint (SOF, Army, Navy, AF, MC) with OP Experience
CIRPAS	- UAV Field, Flt. Support
IS Dept. (GIGA Lab)	- Networks: Performance, Architecture, Vulnerability Assessment, DoS Collaboration; 3D Terrain, Targeting
OR Dept.	- M&S, MOPs, Human Systems Integration, Insurgency Analysis
CS Dept.	- Networks, Encryption, DoS
DA Dept.	- CONOPS, Mission Analysis
MAE Dept.	- Avionics and Controls, UAVs - AUVs, Undersea Sensor Grids & Coms
ECE Dept.	- Covert Networks, IED Detection and Jamming, Smart Antennas, LPI/LPD
Met Dept.	- Local Meteorology, Radar Threat, EO Performance
Meyer Instit. - Systems Engineering, MMALV	
Instit. for M&S - Red Team Intent	
CDTEMS	- Funding
AF Force Protection Battlelab: Sensor Cluster	
ONR/NRL 113: Experiment Support	
MIT/ ONR : EWall Collaboration and Data Fusion Testbed	
Virginia Tech: Antennas	

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

USASOC: SOF Personnel

A.F. Big Safari: Funding

Office of Force Transformation: Funding, Wolf PAC, TACSAT

VC-6: TERN UAV Flight Support

SPAWAR: GIG-EF

NSA NTIO: SIGINT

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

AFSOC: UAV Operations

Camp Roberts ANG : Vehicles, Small Arms

NAVSOC: NAVBOARD

DLI: Language, Team Support

Inter-4 :
 - Tacticomp, NAVBOARD, UWB

Redline Communications: OFDM/ 802.16

Mesh Dynamics – Multi-Radio Mesh

ITT: Mesh

SAVY: RFID

CenGen: SecNet-11 for MANET

GENEX Technologies: Sensors & UAV Payloads

Fortress Technologies: Encryption

PowerWAN: Power Grid WAN

Rajant: BreadCrumb

Flarion: 802.20/OFDM Mobile Coms

Media Group: NOC Architecture

Evidenced Based Research: C2

MCTSSA: Ruggedized PDA, Radio Coms



NPS TNT FY05

Assets and Network Building Blocks

- **Light Reconnaissance Vehicle** - Local and Global C3I, UAV Control
- **Persistent Surveillance Mesh Networking Solutions**
 - Air Nodes: Multiple tethered balloons and airships with cameras and sensors
 - Mesh Networking Protocols: 802.11b with OLSR, ITT with AODV,
 - Ground Sensor Nodes: Smart Rocks, UWB sensors (LLNL), Motion Detectors
 - Self-forming / self-healing solutions
- **Multi-path Networks** (802.11b, 802.16/OFDM, 802.20, Mesh, UWB (LLNL), Iridium, Globalstar) with complexity management
- **802.16/OFDM and 802.20**
 - 100 mi 802.16/OFDM backbone utilization with reach-back using Army SATCOMSTA, SPAWAR GIG-EF, DREN
 - Airborne, ship, and mobile ground (LRV)



TNT Testbed Sensor-UV Networking Capabilities

Unmanned Vehicles

- **UAVs**
 - Coupled video turret, small UAV flight control, and PVNT 3D terrain capability for target lock-on and 1-2 m location accuracy on moving and stationary targets
 - Morphing Micro Air-Land Vehicle
 - Cooperative behavior of multiple UAVs (autonomous landing)
 - Control of multiple UAVs over network

- **AUVs**
 - FL Sonar
 - Autonomous operation with vehicle tracking
 - Mine locating in littoral
 - SA in TNT

Smart Antennas – ship, UAV, ground vehicle; non-rotating tracker

RFID- active, passive, and UWB



TNT Testbed Sensor-UV Networking Capabilities (continued)

Network Operation

- TOC/NOC Architectures: fixed, deployable, mobile, man-pack

Global Connectivity

- TACSAT
- GIG, DREN

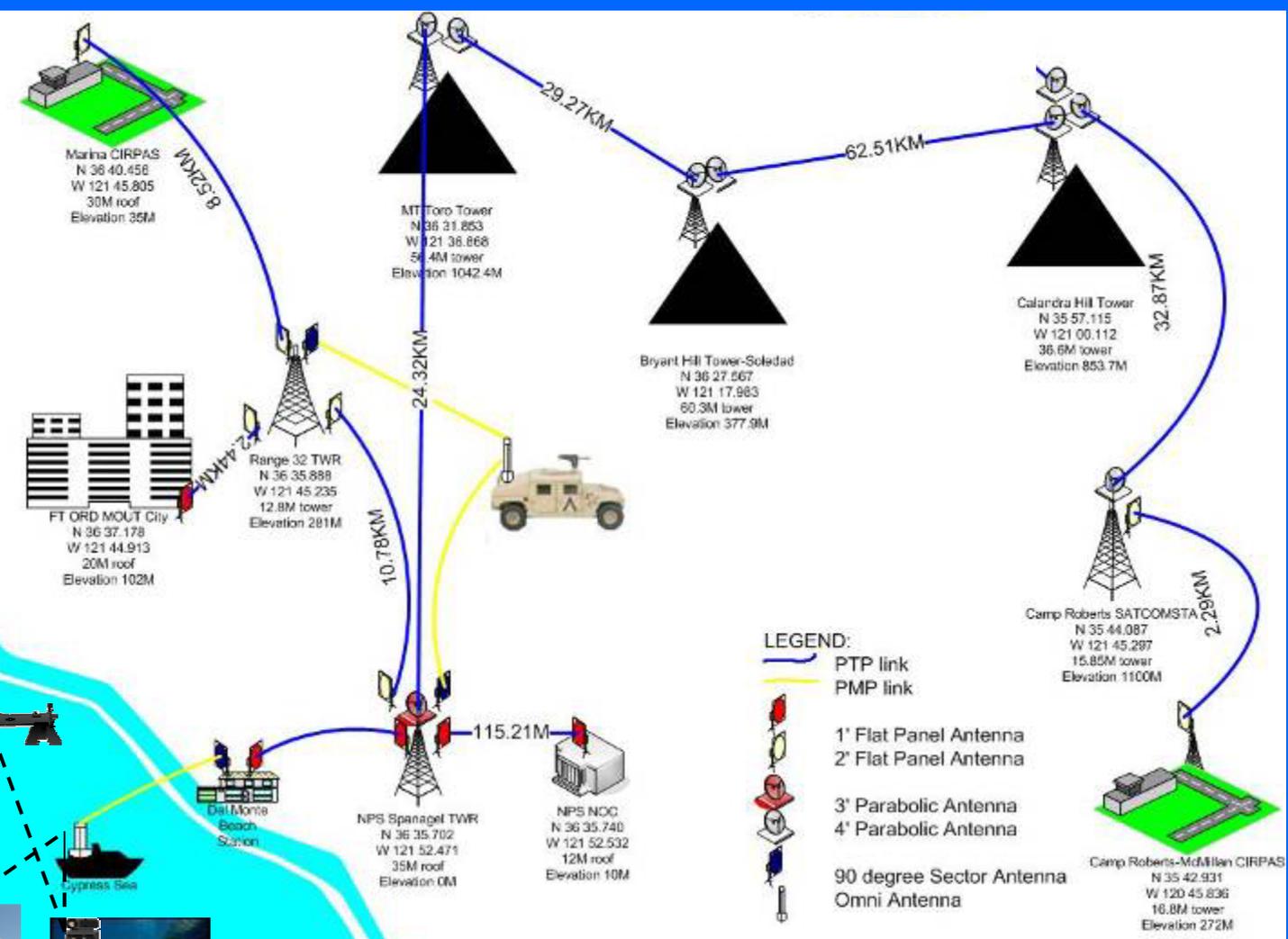
Applications: Collaborative Technologies

- Groove
- SA Agents
- EWall



TNT Testbed Humanitarian Operations Support Capabilities

- **Rapid integration of long-haul (OFDM 802.16, Satellite, EPLRS) and short-haul (ITT, 802.11, 802.20, UWB) wireless networking segments into the seamless ad hoc mobile communications service**
- **Rapid integration of manned-unmanned vehicles and geographically distributed sensors**
- **Multipath (multiplatform) self-organizing mesh**
- **Global connectivity to the Humanitarian Operations Area**
- **Perimeter surveillance and IED identification**
- **Tagging and personnel tracking**
- **Sharing logistics medical supplies tracking with NGOs**
- **Global and local collaboration with NGOs for action planning and emergency response**
- **Collaborative real-time identification, biometrics, radiation, and other sensor data analysis**



802.16/OFDM Backbone

33 Mbps, 5 ms latency, ~100 mi

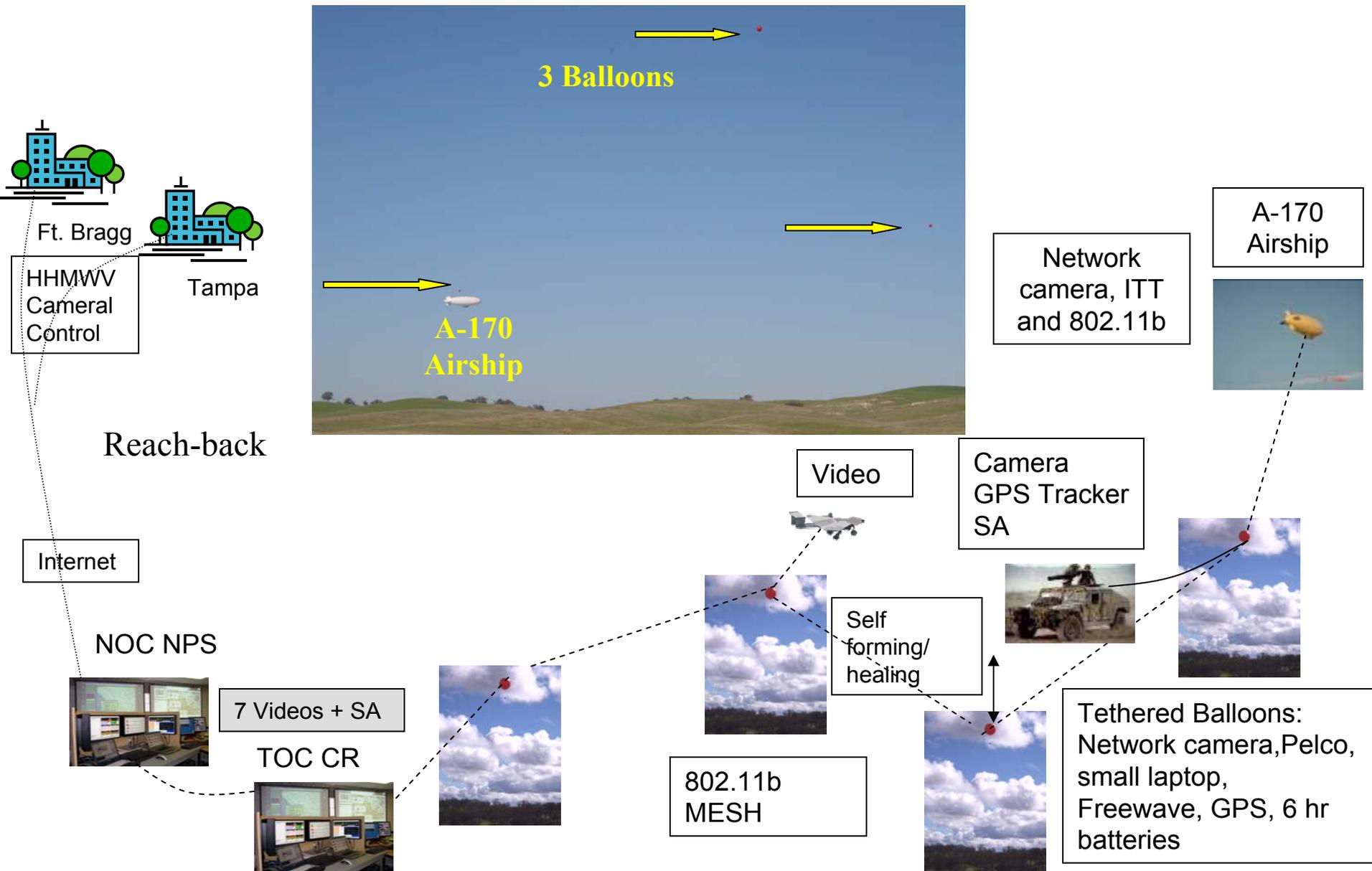
Longest leg ~38 mi



Stretching the Sensor-UV Mesh into the Air

(TNT 05-1, Nov 2004)

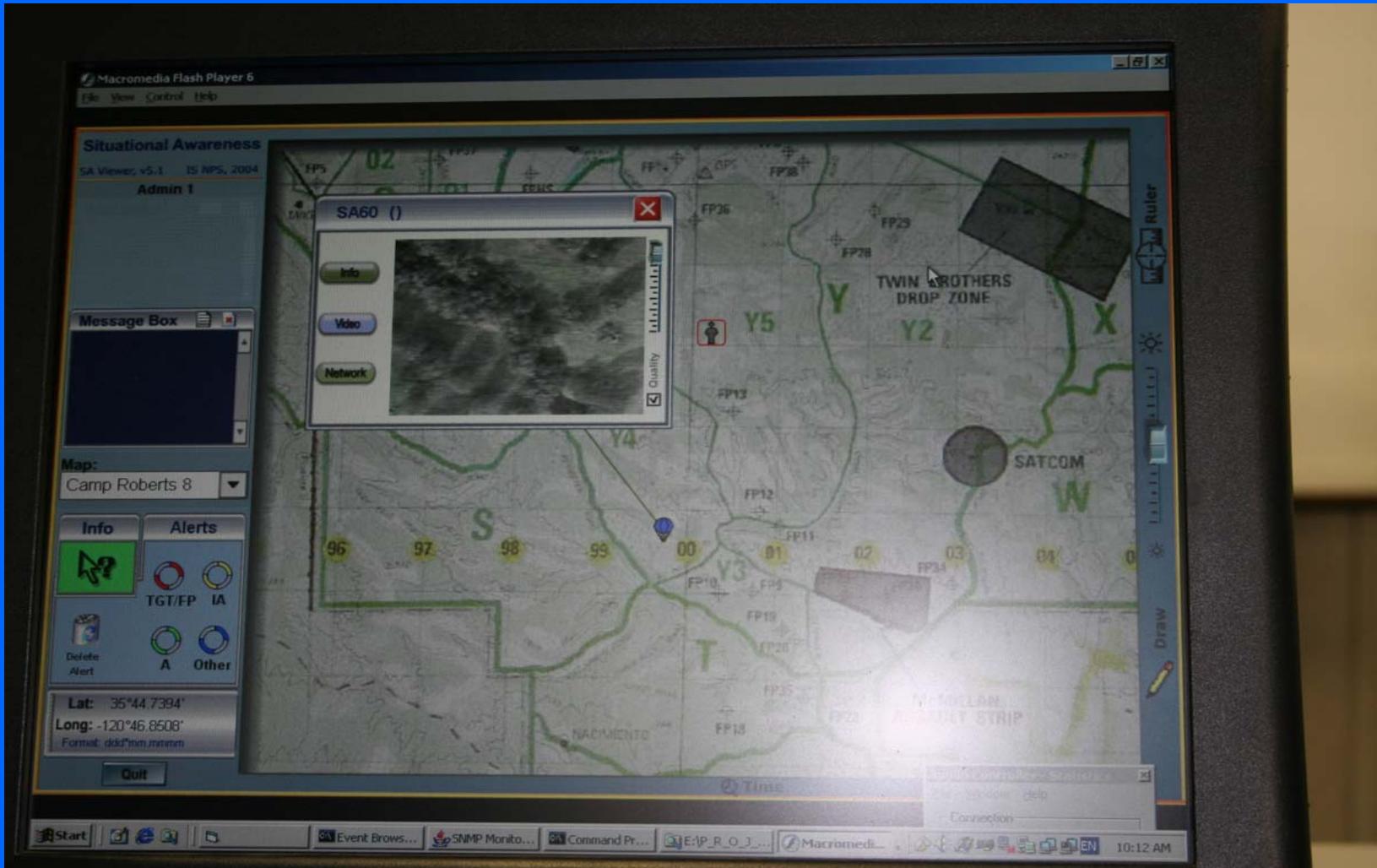
MESH Topology





TNT 05-1, Nov 2004

Video from SA-170 Airship via 802.16/OFDM and Situational Awareness View at TOC



Integrating Air Mesh with NGO/Military Vehicles and Vessels



Improved Camp Roberts TOC



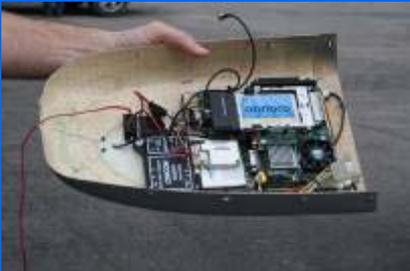
Cypress Sea Approaching USCGC HAWKSBILL – Radiation Detection



Surrogate Light Reconnaissance Vehicle



VC-6 with TERN UAVs



TERN Network Payload

Balloon Payload



Stretching the Wireless Mesh to Sea

Cypress Sea NOC

Cypress Sea Support Boat



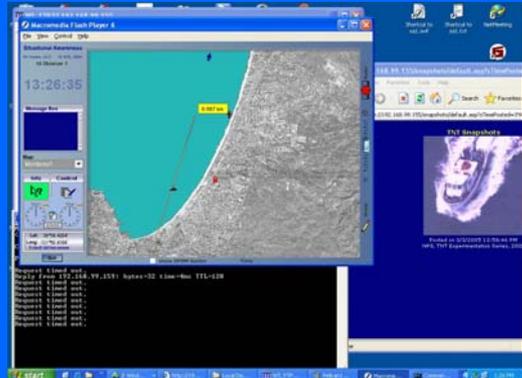
Pelican 802.16/ OFDM Payload



SA for Cypress Sea, Pelican, Pelican Video



Resolution Target for EO Performance Prediction



ARIES AUV



NAVBOARD

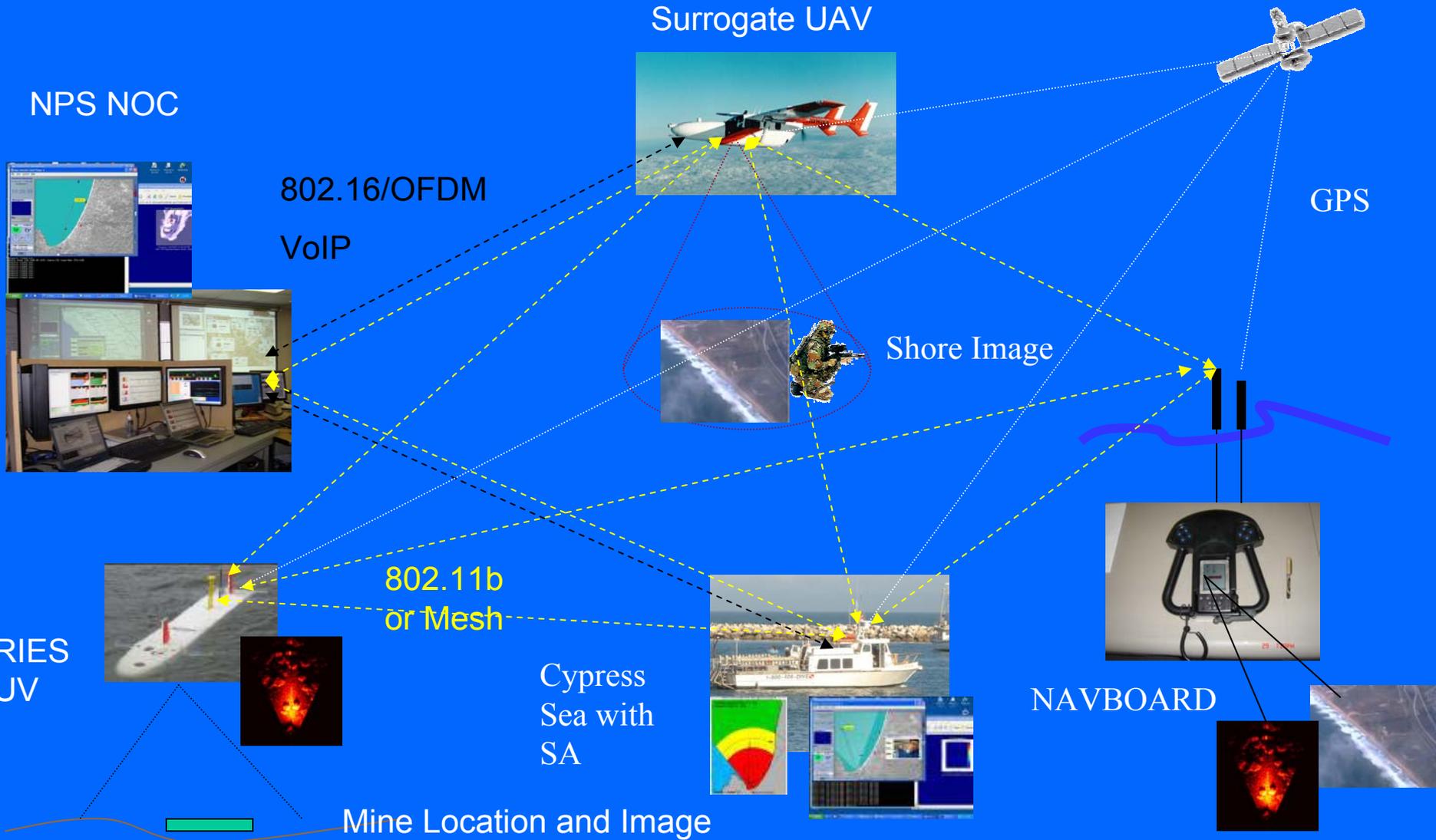


Multipath Networking: Adaptation to SOF Units Ad-Hoc Capabilities



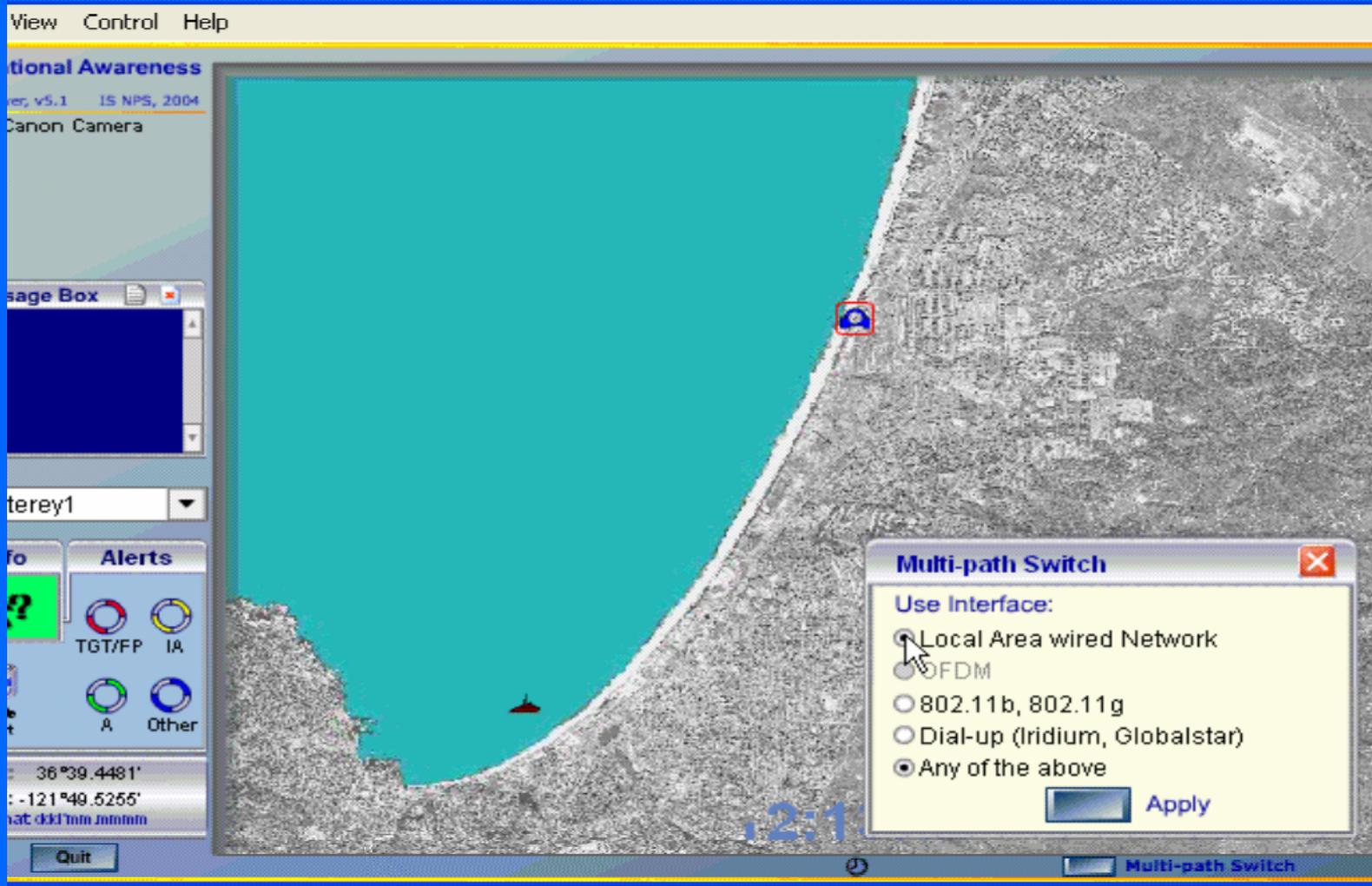
TNT 05-2 Feb 05

Above and Below Water Situational Awareness for Combat Diver





SA Switch for Multipath Human-in-the-Loop Adaptation: SOF crews can switch the network to the mode, which is only available at the moment





TNT 05-2, Feb 2005

Network Aware Sensor-UV Grid

Macromedia Flash Player 6

File View Control Help

Situational Awareness ¹³ Sound: true

SA Viewer, v5.1 15 NPS, 2004

TC3 Agent

Message Box

Sensor: TC3 Agent
Video motion detected.

Map: Camp Roberts 2

Info Alerts

TGT/FP IA

Delete Alert A Other

Lat: 35°46.9585'
Long: -120°46.3473'
Format ddd°mm.mmm'

Quit

TC3 Agent (131.120.178.245)

Info

Video

Network

TC8 (131.120.176.50)

Node Network Status

Response time: <1 ms

Packet Loss: 0

Throughput IN: 9.85 Kbps

Throughput OUT: 3.94 Kbps

Packet Size: 181 Bytes

The screenshot displays a web-based interface for situational awareness. The main area is a map of Camp Roberts, showing various landmarks like 'LAKESIDE' and 'CAMP ROBERTS'. A green figure represents a sensor (TC3 Agent) and a red figure represents another node (TC8). A yellow line connects them. Two windows are open: one for TC3 Agent showing a video feed and another for TC8 showing network statistics. The interface includes a message box, map controls, and a status bar with coordinates.



Peer-to-Peer Data Sharing with NGOs via the SA Agents Representing Sensors and Decision Makers

Macromedia Flash Player 6
File View Control Help

Situational Awareness 7 Motion: true 1
SA Viewer, v5.2 IS NPS, 2004
Alex

Message Box
Sensor: Alex
Video motion detected.

Map:
Camp Roberts 8

Info **Alerts**
TGT/FP IA
Delete Alert A Other

Lat: 35°43.9354'
Long: -120°47.1371'
Format: ddd°mm.mmm'

Quit

Alex (131.120.178.85)
Info Video Network
Quality

TWIN BROTHERS DROP ZONE
SATCOM
McMILLAN ASSAULT STRIP

Time



Data Fusion with Civil-military Operations Community: SA Agents output is captured by the NPS interface to the EWall News Server

The screenshot shows the EWall NewsView application window. The title bar reads "EWall NewsView" and the menu bar includes "File", "View", and "Help". The status bar at the top indicates "Client updated at 5:03 PM", "Server updated at 5:03 PM", "Running for 0 hours", "Showing 19 stories in 16 cards", and "Using 11 MBytes".

The main content area displays a grid of activity logs for various categories:

- Alex (Green background):** Includes a video player for "SA: 16:54: motion." and two SA agent icons with timestamps "SA: 16:48:45 registered." and "SA: 11:39:06 registered."
- Tampa2 (Pink background):** Includes two SA agent icons with timestamps "SA: 11:30:13 logged off." and "SA: 11:30:01 registered."
- Canon Camera (Yellow background):** Includes six items: a SA agent icon ("SA: 13:40:08 logged off."), a camera icon ("SA: 13:39:41 registered."), a SA agent icon ("SA: 13:34:38 logged off."), a camera icon ("SA: 13:34:27 registered."), another camera icon ("SA: 13:30:58 registered."), and a SA agent icon ("SA: 13:30:52 logged off.").
- TOC (Orange background):** Includes three SA agent icons with timestamps "SA: 11:34:52 registered.", "SA: 11:34:30 logged off.", and "SA: 11:30:23 registered."
- NOC (Purple background):** Includes two SA agent icons with timestamps "SA: 16:47:19 registered." and "SA: 11:24:10 registered."

The Windows taskbar at the bottom shows the Start button, several open applications including "http://131.120.176.51/...", "Naval Postgraduate Sch...", "cap1.JPG - Paint", and "My Documents", and the system tray with the time "5:03 PM".



Agent-EWall integration creates network-centric memory mechanism for developing shared understanding of SA events

The screenshot displays the EWall NewsView application interface. At the top, it shows system status: "Client updated at 4:58 PM", "Server updated at 4:58 PM", "Running for 5 hours", "Showing 26 stories in 23 cards", and "Using 17 MBytes".

The main interface is a grid of agent status cards. The left side of the grid is color-coded by role:

- Alex** (Green): 10 cards showing "Video motion" at various times from 4:58 PM to 11:39 AM.
- Tampa2** (Pink): 2 cards showing "logged off" and "registered" at 11:30:13 and 11:30:01.
- Canon Camera** (Yellow): 3 cards showing "logged off", "registered", and "logged" at 13:40:08, 13:39:41, and 13:40:08.
- TOC** (Orange): 3 cards showing "registered", "logged off", and "registered" at 11:34:52, 11:34:30, and 11:34:10.
- NOC** (Purple): 1 card showing "registered" at 11:34:10.

A central window displays a map titled "Situational Awareness" with a "Message Box" and "Map" controls. The message box contains the text: "Sensor: Alex with no motion detected." The map shows a geographic area with various markers and labels like "TWIN BROTHERS DRUG ZONE", "SATCOM", and "M. MILLAN ASSAULT STRIP".

The bottom of the screen shows a Windows taskbar with the Start button, several open applications (EWall NewsView, Internet Explorer, Paint), and a system tray with the time 4:58 PM and a Recycle Bin icon.



Stretching the Wireless Mesh and Collaborative Technology to Sea: Radiation Detection and Boarding Party Support (NPS-LLNL)

Global Civil-Military Collaboration via the TNT testbed



OFDM Backbone Detail



LRV DETAIL

Ship-to-Ship

Ad-Hoc Mesh



Target Ship Enters Monterey Bay; Collaboration with TACSAT for Ship ID



The screenshot shows a Windows XP desktop with a workspace application. The workspace has a menu bar with 'File' and 'Edit', and a toolbar with 'Pictures' and 'Add P'. Below the toolbar is a navigation bar showing 'Picture 3 of 3'. The main workspace area is divided into two panes. The left pane displays a graph titled 'Pulse Amplitude vs Frequency'. The right pane shows 'Workspace Members' and a 'Chat' window.

Workspace Members:

- In Workspace
 - Alex Bordetsky/Naval Postgra...
- Online
- Offline
 - Boarding Officer
 - Jadon Klopson/Naval Postgraduate ...
 - Joseph Herzig/Naval Postgraduate ...
 - Les Nakae
 - Omar Medina
 - Omar Medina
 - Stephen Burdian/Naval Postgraduat...

Chat:

Vonda Olsavsky/Naval Postgraduate School:
2/28/05 11:49 AM
Just to pass along...Cypress Sea made positive ID on TOI based on TACSAT info and have sent over a boarding team...

Vonda Olsavsky/Naval Postgraduate School:
2/28/05 11:55 AM
to further inform...we cannot get mesh connectivity between Cypress Sea and Hawksbill and will be putting them both on the

Common Tasks:

- Add Tools
- Set Alerts
- View Workspace Properties
- Send Message to Members

Graph: Pulse Amplitude vs Frequency

The graph plots Amplitude (dBm) on the y-axis (ranging from -45.0 to -20.0) against Frequency (MHz) on the x-axis (ranging from 9410.0 to 9470.0). The data points are represented by red '+' markers, showing a dense cluster of points between 9420.0 and 9470.0 MHz, with a secondary cluster around 9430.0 MHz.

Taskbar:

The taskbar shows the 'start' button, several application icons, and open windows for '4 M...', '2 W...', 'Inbo...', '2 M...', and '2 G...'. The system tray shows the time as 4:00 PM and a network icon showing 8.57 KB.



Radiation Awareness: Collaboration with LLNL for Radiation Analysis via the TNT

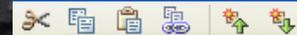


LLNL Experiment - Pictures - Groove

File Edit View Options Help

Workspaces

groove



Show Picture List

Picture 2 of 3



Workspace Members

In Workspace

Alex Bordetsky/Naval Postgra...

Online

Offline

- Boarding Officer
- Jadon Klopson/Naval Postgraduate ...
- Joseph Herzig/Naval Postgraduate ...
- Les Nakae
- Omar Medina
- Omar Medina
- Stephen Burdian/Naval Postgraduat...

Invite to Workspace:

More

Enter name or email

Go

Chat 1

2/28/05 12:46 PM

Note the new files just posted...total of 6 neutron pod files as of now...

Les Nakae: 2/28/05 12:57 PM

First Neutron file looks poisson, 2nd shows some multiplication. Now checking Gamma files.

Les Nakae: 2/28/05 12:59 PM

Sorry, I meant correlation, not multiplication. Darrell

Type here

Go

Common Tasks

- Add Tools
- Set Alerts
- View Workspace Properties
- Send Message to Members

Files

Discussion

Notepad

Calendar

Pictures

Sketchpad

(2) Microsoft PowerPoint

8.57 KB

start

4 M.. 2 W.. Inbo... 2 M.. 2 G...

4:02 PM

UWB sensor link joins the Mesh

Macromedia Flash Player 6

File View Control Help

Situational Awareness

SA Viewer, v5.3 IS NPS, 2005
TAU 1

Message Box

Map: Camp Roberts 1

Info Alerts

Lat: 35°42.9406'
Long: -120°45.8439'
Format: ddd°mm.mmm'

Quit

LLNL-UWB MESH ()

Info Video Network

UWB Communication

TAU 1 ()

Node Network Status

Info Response time: ms
Packet Loss:
Throughput IN: Kbps
Throughput OUT: Kbps
Packet Size: Bytes

Video

Network



The screenshot displays the SA Viewer interface. A central map shows a terrain with a red dashed line and a green line representing a UWB sensor link. A window titled 'LLNL-UWB MESH ()' is open, showing a 'UWB Communication' window. Another window titled 'TAU 1 ()' is open, displaying 'Node Network Status' with a table of metrics. The interface includes a 'Message Box', 'Map' dropdown, 'Info' and 'Alerts' buttons, and a 'Quit' button. The top of the window shows 'Macromedia Flash Player 6' and a menu bar with 'File View Control Help'.

Metric	100	1000	10000
Throughput IN: Kbps	100	1000	10000
Throughput OUT: Kbps	100	1000	10000
Packet Size: Bytes	100	1000	10000

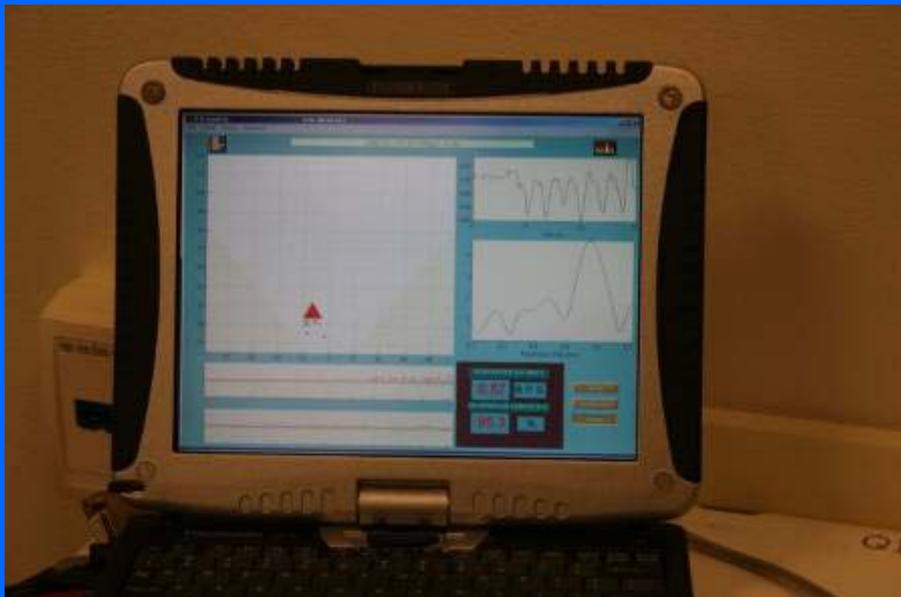
Extending the Mesh by the UWB links enabling IED Tracking and Motion Detection Through Walls and Metal Structures



LLNL UWB

LLNL UWB Thru-Wall Motion Detection

Motion detection by camera with UWB link thru 3 walls into TNT mesh



Breathing Detection:
LLNL UWB Radar
thru wall



What's next:

- Learning the network integration constraints
- Deriving policies for on-demand civil-military sensor-unmanned vehicle networking
- Exploring collaboration and data sharing models for Humanitarian, Tactical, and Network Operation Centers



Learning constraints: UAV surveillance perimeter for the SOF-Humanitarian Operations Area

My Computer hs_err_pid1...

Shortcut to sa1.swf Shortcut to sa1.txt NetMeeting Canon-Pelco Viewer.

http://192.168.98.178/vc4.swf - Microsoft ...

File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search

Address http://192.168.98.178/vc4.swf Go Links

TERN 192.168.98.178

Done Internet

NetManager Pelco350.zip

Player 6

LRV ()

Node Network Status

Info Node disconnected!

Video Throughput IN: 100 1000

Throughput OUT: 100 1000

Network Packet Size: 100 1000 10000

4.486 km

TAU 1 (192.168.98.101)

Node Network Status

Info Response time: <1 ms
Packet Loss: 0

Video Throughput IN: 7.65 Kbps

Throughput OUT: 3.43 Kbps

Network

start

http://192.168.9... http://192.168.9... Tern_UAV Macromedia Flash... LView Pro 1.8/16 11:40 AM



Larger (still feasible) perimeter but lower video quality

The screenshot displays a Windows desktop environment with several open applications:

- Internet Explorer:** A window titled "http://192.168.98.178/vc4.swf - Microsoft ..." is open. The address bar shows "http://192.168.98.178/vc4.swf". The main content area displays "TERN 192.168.98.178" above a video player showing an aerial view of a field.
- Player 6:** A window titled "Player 6" is open, displaying a 3D topographic map. A red dashed line traces a path on the map. A yellow callout box indicates a distance of "7.645 km". The map includes a ruler and various navigation tools.
- Node Network Status:** A small window titled "TAO T (192.168.98.101)" is open, showing network performance metrics:

Node Network Status	
Info	Response time: <1 ms
Info	Packet Loss: 0
Video	Throughput IN: 11.28 Kbps
Video	Throughput OUT: 5.07 Kbps
Network	Throughput IN: 100
Network	Throughput OUT: 100

The taskbar at the bottom shows the Start button, several open browser windows, and the system clock displaying "11:44 AM".



Looking inside the building via the UAV: UWB solution

The screenshot displays a Windows desktop environment with several open applications. The primary focus is a web browser window titled "PELONET 300 homepage (LIVE VIDEO) - MICROSOFT I...", which shows a live video feed of an aerial view of a building complex. The video feed is titled "TERN 192.168.98.178".

Overlaid on the video feed is a "Node Network Status" pop-up window for "LLNL-UWB MESH (192.168.98.93)". The status is as follows:

Category	Value
Response time	<1 ms
Packet Loss	0
Throughput IN	45.06 Kbps
Throughput OUT	1.78 Kbps
Packet Size	148 Bytes

Another "Node Network Status" pop-up window is visible for "TERN (192.168.98.101)". Its status is as follows:

Category	Value
Response time	<1 ms
Packet Loss	0
Throughput IN	8.19 Kbps
Throughput OUT	3.90 Kbps
Packet Size	73 Bytes

The desktop also shows a taskbar with the following icons: start, Internet Explorer, Command Prompt, Tern_UAV, and LView Pro 1.0/16. The system clock in the bottom right corner indicates the time is 11:01 AM.

Questions?

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