Sensor Information Technology (SensIT) Program

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http://dtsn.darpa.mil/ixo/sensit%2Easp

Sensor Information Technology (SensIT)

- DARPA IXO funded program (~$30M)

- AFRL/IFGA acting as agent for 17/25 contracts in program (~$17M)

- SensIT Integration, Test, and Demonstration contract with BBNT

    - 42 mo, $3.2M contract to facilitate experimentation

    - integrate and “demonstrate” program technology

    - put the pieces together into a real-world application

        - Transporter Erector/Launcher (TEL) ambush

        - Military Operations in Urban Terrain (MOUT)

SensIT Objectives

• This program is NOT developing sensors.
It IS developing the methods and capabilities to most effectively and efficiently exploit sensor information.

• Develop innovative and effective software for producing and communicating sensor information

• Demonstrate dense distribution of networked sensors (sensors distributed near threats)

• Leverage effective and low-cost prototyping kits based on commercial off-the-shelf (COTS) components and/or government furnished equipment (GFE)

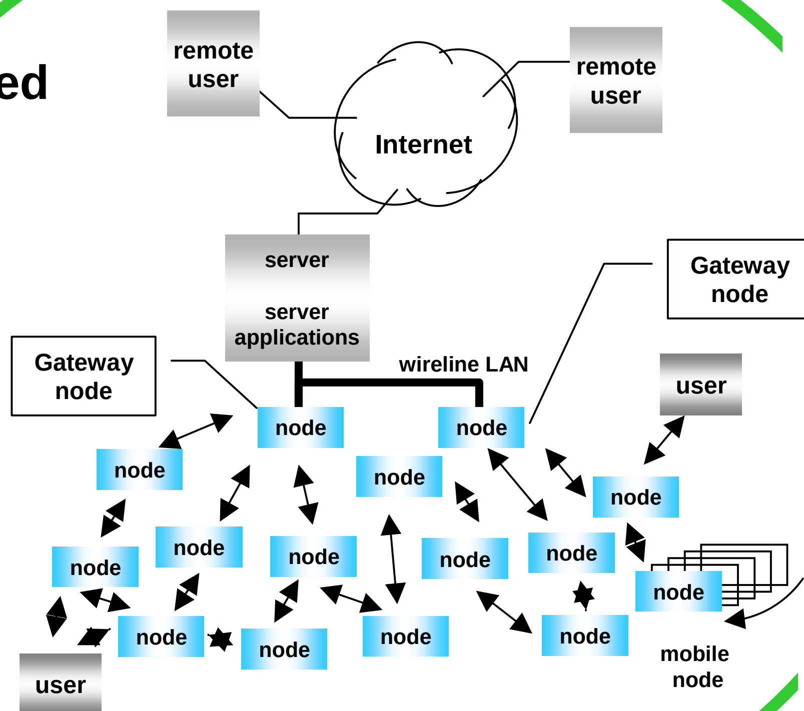
SensIT Thrusts

Critical Information Technology Solutions

multihop, self-assembled wireless networks

diffusion network protocols

adaptive and reconfigurable tactical sensing



network signal processing

database languages and applications

nanoencryption

SensIT Community Common Platform

Battlefield Surveillance

- Targets
  - personnel
  - wheeled
  - tracked
  - fixed wing
    - UAV
  - rotary wing
- Function
  - detection
  - identification
  - location
  - tracking
- Environment
  - open field
  - MOUT
- Application
  - personal
  - platoon
  - battalion
  - border and base security
  - air campaign
  - land mine replacement
- Users
  - dismounted soldiers
  - Command post
  - Force level
  - intelligence
- Sensors
  - seismic
  - acoustic
  - infrared motion
  - environmental
  - chem/bio
  - imaging

Current Technology

- Tactical Automated Security System (TASS)
- Tactical Remote Sentry System (TRSS)
- Remotely Monitored Battlefield Sensor System (REMBASS (II))
- Physical layer link
  - 12.5 kHz channel single frequency transmit only

Current Technology

- Current technology based on:
  - transmit only nodes
  - binary state event detection
  - non-programmable
  - large
  - high power
  - high cost
  - *long range detection paradigm*

What is Unique About SensIT

SensIT

- provides a wide range of user benefits
- through <u>integrated</u> information technologies

Unique User Benefits Provided by SensIT

Enabling Information Technology

	Multi-Tasking	Dynamic Re-tasking	Scalable	Graceful Degradation	Self organizing	Longevity	Node/User mobility	Ease of Use	Performance
Advanced Routing Techniques	X	X	X	X	X	X	X	X	
Mobile Code	X	X	X	X	X			X	X
Declarative Language Interface	X	X	X		X			X	
Tactical Oriented user interface			X	X	X		X	X	
Collaborative Processing			X		X	X			X
Advanced Communications Techniques			X	X	X	X	X	X	
Distributed Processing	X	X	X	X	X	X	X		X
Distributed Database Structure		X	X	X	X	X	X		
Automated management of distributed tasking vs resources	X	X	X	X	X	X	X	X	X

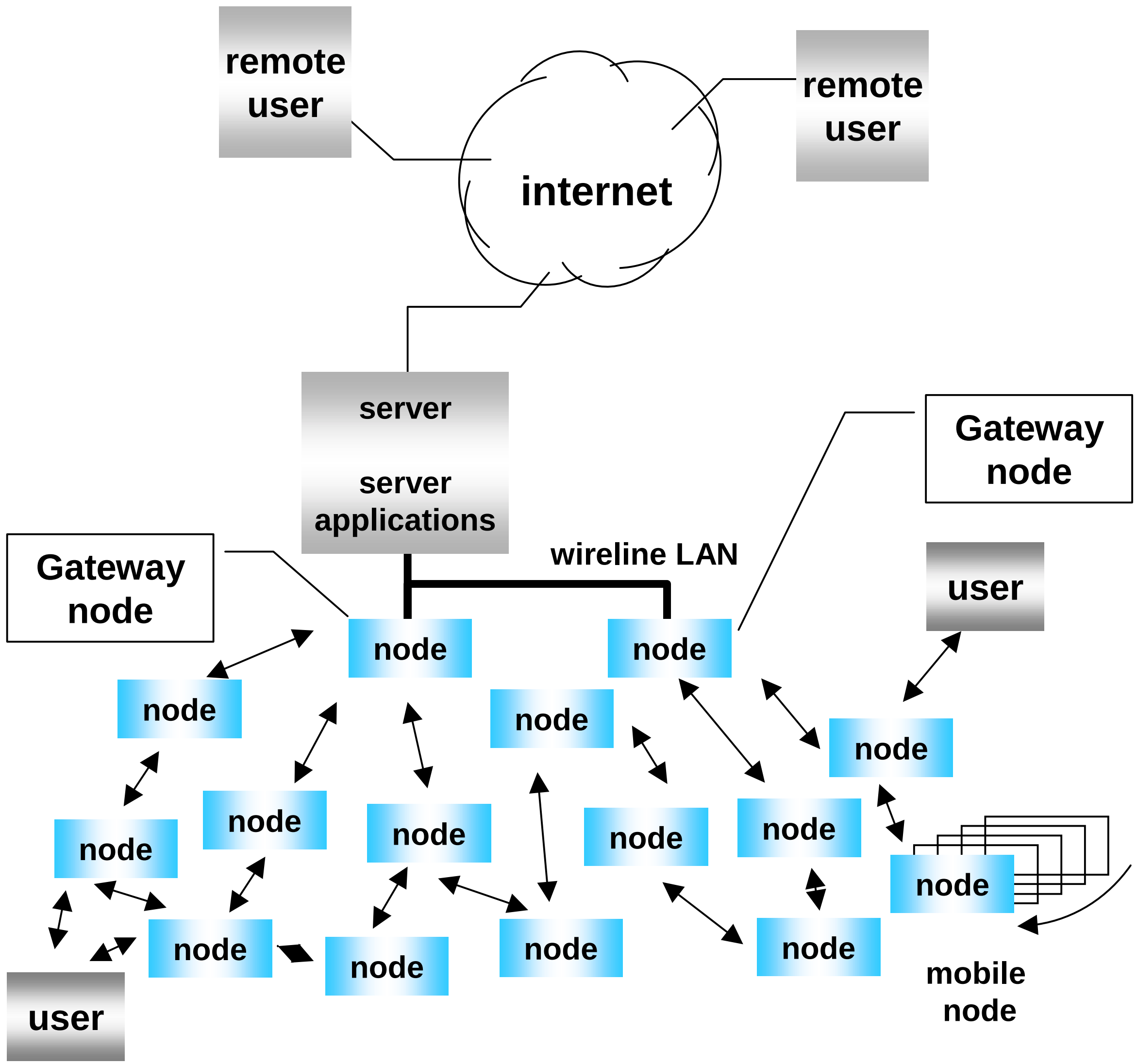
Distributed Sensing Solution

- Benefits:
  - drastically improved signal-to-noise ratio and detection threshold
  - reduced number of threats in sensor “field of regard” - reduced threat identification confusion
  - create sensor diversity
  - create multisensor location diversity
  - enable cooperative sensing

Architecture: Constraints

- **lifetime**
  - multiyear, constant vigilance
- **power**
  - compact cells
- **deployment**
  - diverse methods
- **deployment density -** high
- **comm duty cycle -** low
- **response time -** tolerant to long response time
- **latency** - tolerant of long latency

WINS NG Architecture



WINS NG Platform by Sensoria Corporation

- WINS NG functionality
  - Location
    - GPS
  - Sensing
    - complete sensor support
    - imaging
  - Signal processing and event recognition
  - Self-Assembled Wireless Networking
  - Internet WINS Gateway acquisition

WINS NG Platform

- WINS Architecture
  - Performance
    - Low power
    - Constantly vigilant
    - Available, on-demand processing capability
  - Development
    - standard 32 bit OS
      - support DOD commitment to Windows technology
    - development tools
    - SenseIT products include APIs for:
      - computation
      - signal processing
      - adaptation
  - Low Cost
    - exploit cost reduction of COTS Windows CE platform

Package

- Sealed, accessible package:
  - Processor
  - Preprocessor
  - Rechargeable Battery Pack

Prototype Node Platform

- Sensoria WINS 2.0 Nodes
  - 167MHz HP SH4 processor; LINUX
  - 64MB memory; 64MB flash
- Sensing:
  - 4 (interchangeable) analog input channels
  - Geophone, Microphone, Passive InfraRed
  - Onboard DSP
- Radios: two 2.4GHz
- Power: 12 V DC w/ external power pack
- GPS antenna
- Quantity: 90 built, 30 more due 3Q02
- Sensoria WINS 2.0 Imager

Sensors

- Select either seismic, acoustic, or IR
  - Geophone seismic sensor
  - Acoustic Sensor
  - IR Motion Sensors
    - one to four
  - Select custom sensor interfaces
    - GEC-Marconi program

Field Test History

•	Sept 96	29 Palms	USMC data collection
•	Sept 96	29 Palms	USMC Desert Fire
•	Dec 96	29 Palms	USMC Steel Knight
•	April 97	29 Palms	USMC Desert Scimitar
•	June 97	Aberdeen Proving Ground	US Army
•	October 97	USS Rushmore	US Navy
•	December 97	29 Palms	Steel Knight
•	February 98	Army NTC	US Army Data Acquisition

Field Tests/Exercises

- August 2000, MCAGCC, Twenty-nine Palms, CA
  - WINS 1.0 nodes
- March 2001, MCAGCC - Twenty-nine Palms, CA
  - Standalone demos
- November 2001, MCAGCC - Twenty-nine Palms, CA
  - 70 WINS 2.0 nodes
  - Challenge Problem: Autonomous, real-time, tactical target localization, tracking, classification, and image capture, on a large distributed ground sensor network
- December 2001, MCAGCC - Twenty-nine Palms, CA
  - Steel Knight, 7th Marine Regiment Combined Arms Exercise
  - Image capture, transmission and display

FY00 Experiment Goals

- Wring out basic end-to-end functionality & operability
- Establish performance baseline
  - e.g. sensing performance, network traffic, latency, scaling, survivability, etc.
- Highlight unique features (expand as devel. permits)
  - User Benefits
    - Multiple users/tasking, dynamic (re)tasking, basic collaborative processing
  - Enabling Technologies
    - Declarative languages, mobile code, advanced routing techniques, collaborative processing, tactical user interface
- Gather data to aid PIs in further development efforts

Program must balance experiment "reach" vs. "risk"
Requires prioritization

FY00 Experiment Scenario - Overview

- Transporter Erector/Launchers (TELs) are on the move
- Command needs to determine when and where they are moving.
- Plan
  – Deploy sensor groups over a wide area.
  – Use sensors to determine TEL traffic patterns.
  – Send in Special Operations Force (SOF) to confirm identification and destroy TELs.

Execution

- Potential Locations
  - 29 Palms
  - Aberdeen Proving Grounds
  - Other
- Traffic "Targets"
  - Heavy trucks, tanks, light vehicles (e.g. HMMVs), dismounted personnel, other
- Target Timeframe
  - August 2000
- Experimentation Practicalities
  - Use battery eliminators (i.e. nodes are AC powered)
  - Use Ethernet or other hard wired connection to collect data
  - Some level of experiment monitoring resides on each node

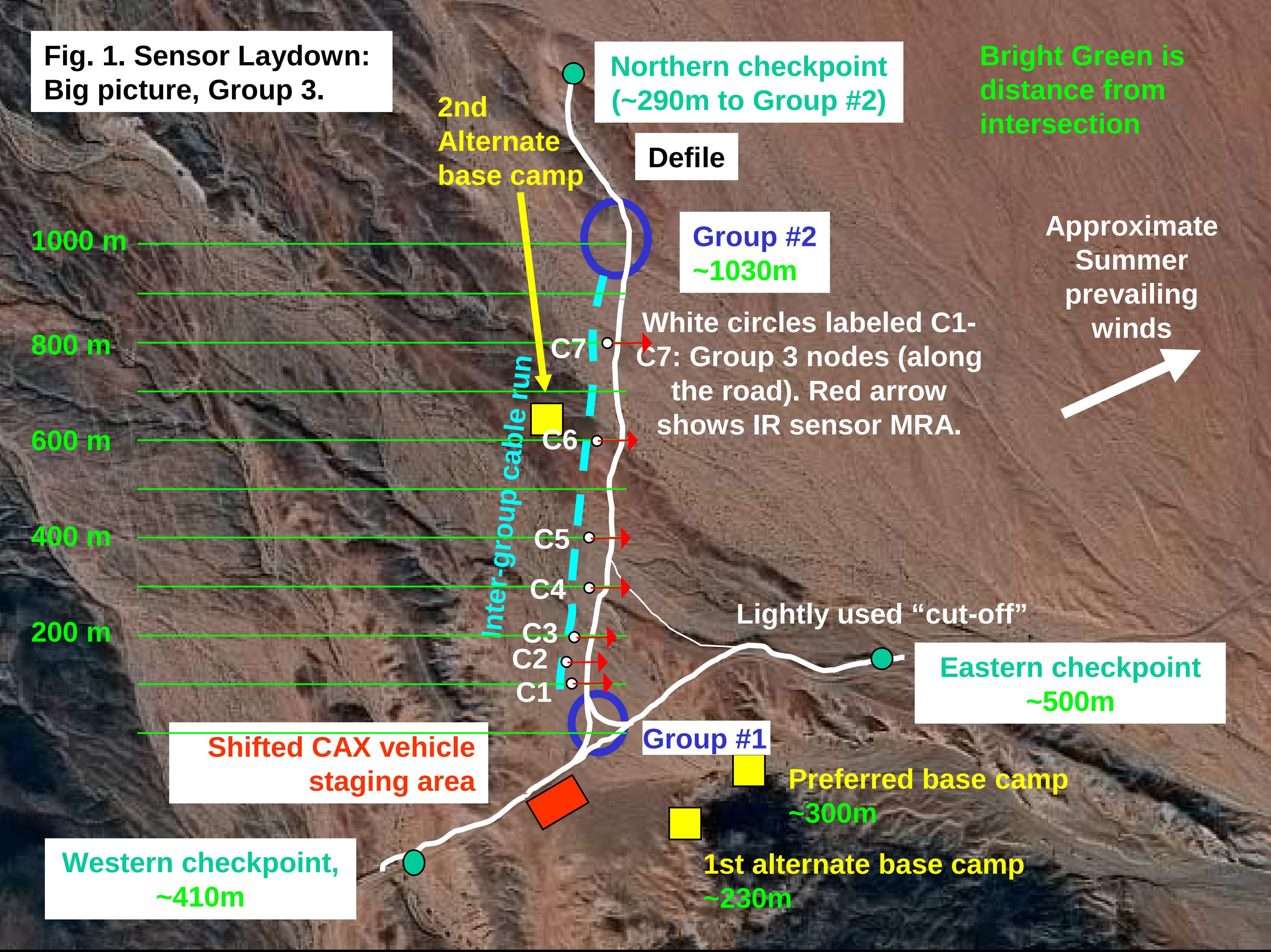


Fig. 1. Sensor Laydown: Big picture, Group 3.
Northern checkpoint (~290m to Group #2)
Bright Green is distance from intersection
2nd Alternate base camp
Defile
Group #2 ~1030m
Approximate Summer prevailing winds
1000 m
800 m
600 m
400 m
200 m
C7
C6
C5
C4
C3
C2
C1
Inter-group cable run
White circles labeled C1-C7: Group 3 nodes (along the road). Red arrow shows IR sensor MRA.
Lightly used "cut-off"
Eastern checkpoint ~500m
Group #1
Shifted CAX vehicle staging area
Preferred base camp ~300m
1st alternate base camp ~230m
Western checkpoint, ~410m

Performers

<u>FY 99 New Starts</u>	
Flexible Decision	Cornell
Reactive Sensor Network	Penn State
Dynamic Sensor Nets	USC-ISI
Sensor Agent Processing Software	Marconi
A Communications Security Arch	TIS Labs
WINS: Wireless Integrated Sensor Net	Sensor Com
SenseIT Integration, Test & Demo	BBN
<u>FY 00 New Starts</u>	
CoSense: Collaborative Sensemaking for Target Recognition and Condition Monitoring	Xerox, PaloAlto
Lightweight Cryptographic Techniques	Northwestern
Sensor Webs of Smart Dust	UC Berkeley
Self Configuring Wireless Transmission and Decentralized Data Processing for Generic SN	Cornell
Location-Centric Distributed Computation & Signal Processing in Microsensor Networks	Univ of Wisconsin

Looking up at Base Camp

Panoramic View from Base Camp


Base Camp Briefing
8/2/2000 09:18


Road Intersection (triangle)


Test Vehicles:
HMMWV, 5-Ton Truck, and Dragon Wagon

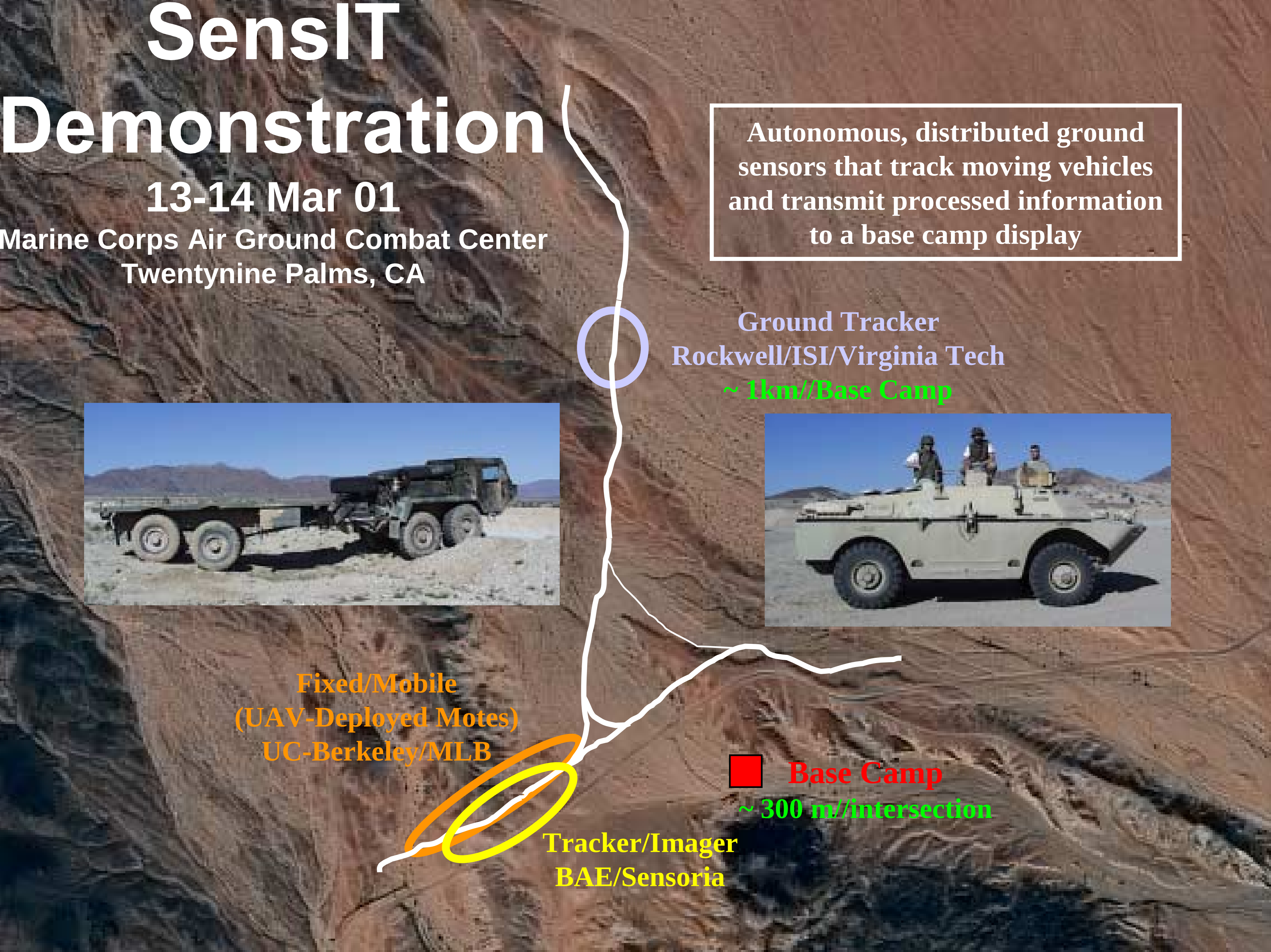
LVS (Dragon Wagon)

Light Armored Vehicle (LAV)

Assault Amphibious Vehicle (AAV)

LAV, DW, AAV Convoy

Dismounted Troops Marching


SensIT
Demonstration
13-14 Mar 01
Marine Corps Air Ground Combat Center
Twentynine Palms, CA
Autonomous, distributed ground sensors that track moving vehicles and transmit processed information to a base camp display
Ground Tracker
Rockwell/ISI/Virginia Tech
~ 1km//Base Camp
Fixed/Mobile
(UAV-Deployed Motes)
UC-Berkeley/MLB
Base Camp
~ 300 m//intersection
Tracker/Imager
BAE/Sensoria

Distributed Tracker - Imager

Hardware: Sensoria
Signal & Collaborative Tracking: BAE SYSTEMS
Network Protocols: USC/ISI

- **Automatic Node Localization & Field Determination**
  - Each node uses GPS to establish it's location & local time
  - Node locations are shared to enable collaborative tracking
  - Clocks are synchronized for detection event characterization
  - Meta Knowledge of road location, expected traffic
- **Automatic Network Configuration**
  - No intervention to set network addresses
  - Routing algorithm insensitive to loss of nodes
- **Distributed / Collaborative Processing**
  - Nodes share detection events and tracking state information
  - Jointly estimate imager trigger point
  - Initial track estimate improves with each detection

Image Display

RF Link

PIR
Seismic
Acoustic
GPS

Sensor Signal Processing
High Level Processing, CPA Estimation
Sensor Fusion

CPA Sharing
Location Sharing
Clock Coordination

Kalman Tracker
Imager Trigger Estimation

Image Capture

Local Node Processing

Collaborative Processing

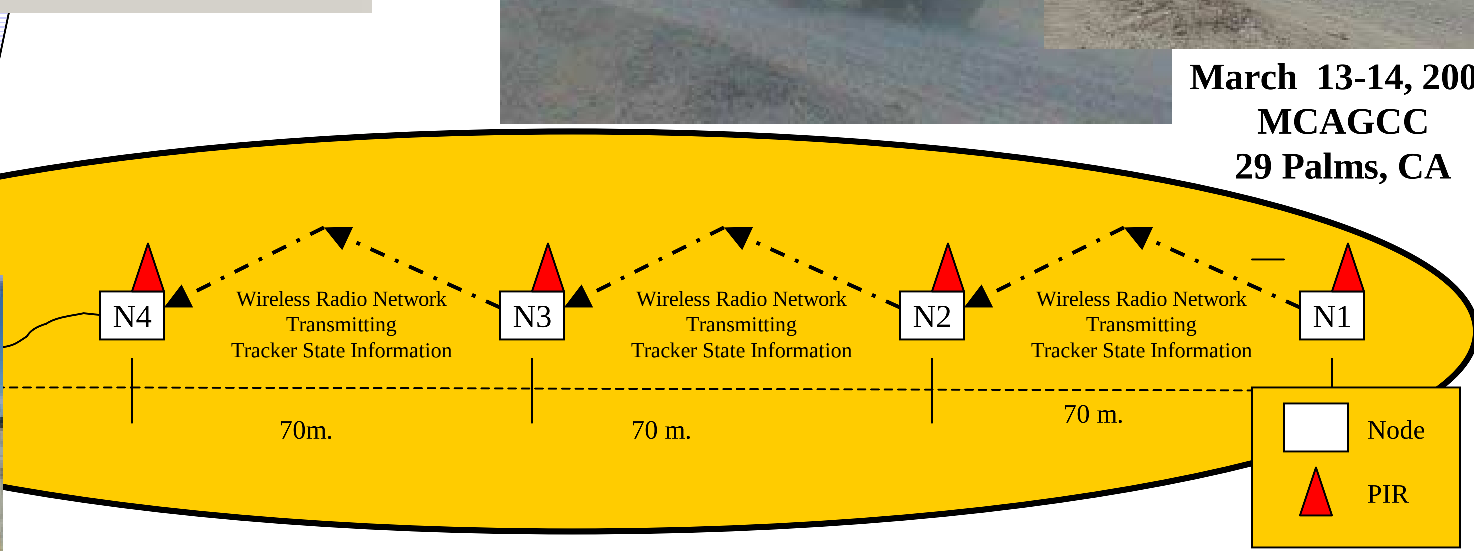
SensIT Imager/Tracker Demo
Sensoria/BAE

Demonstration

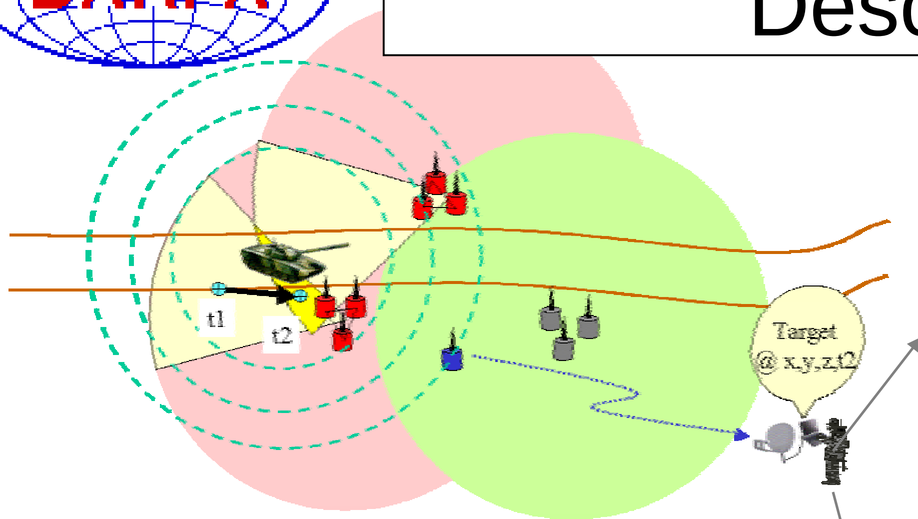
- Track a vehicle as it drives east to west down the road.
- Update the tracker estimates of vehicle speed and location.
- Take a picture when the vehicle is in the image field of view.
- Requires coordination between nodes at all levels from tracking to message passing

Road West of Intersection

March 13-14, 2001
MCAGCC
29 Palms, CA



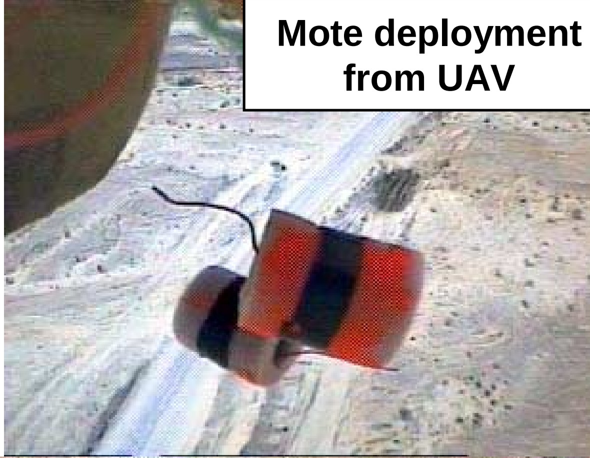
DSN/Sensorware Experiment Description



- At Base Camp
  - Situation status display GUI (running on laptop).
  - Live video feed at 5fps on wireless iPAQ PDA.

- Wave Intensity Comparison – multiple projections are made from seismic signal energy at sensor node clusters.
  - Nine Rockwell HYDRA nodes.
  - Laptop with web cam.
  - COTS 802.11 wireless Ethernet bridge to base camp (~1km).

Berkeley/MLB experiment: Vehicle tracking with a UAV deployed network



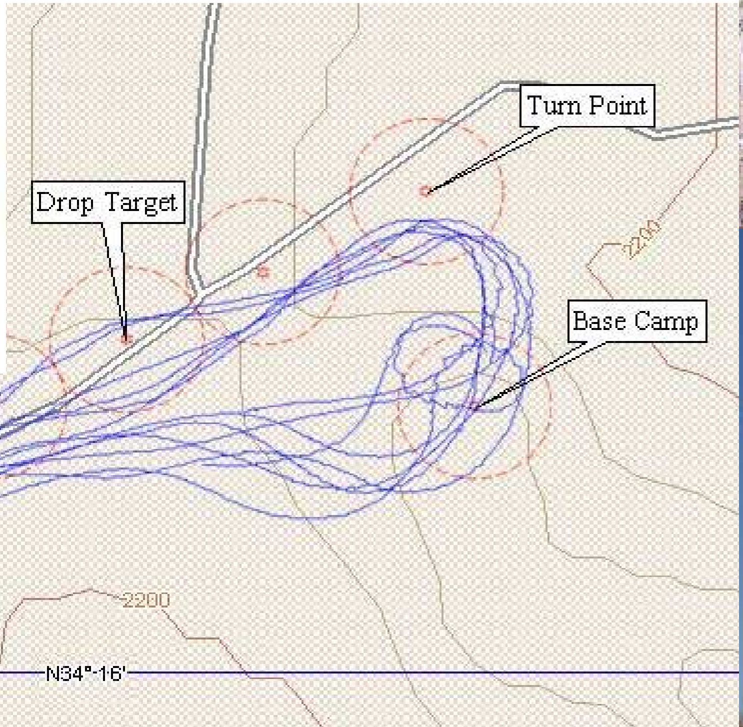
6 wireless sensor nodes were dropped from a 5' UAV, landed at 5 meter intervals, established a multi-hop network, and synchronized clocks.

Passing vehicles caused a change in the local magnetic field. The motes sample their 2 axis magnetometers at 5 Hz, filter and threshold the data, and transmit a time-stamped message to the rest of the network when a vehicle is detected.

A least-squares estimate of vehicle velocity was calculated and stored by every mote for every vehicle, and motes update their estimated position assuming constant velocity vehicles.

Whenever the UAV returned, the network transmitted the vehicle track info.

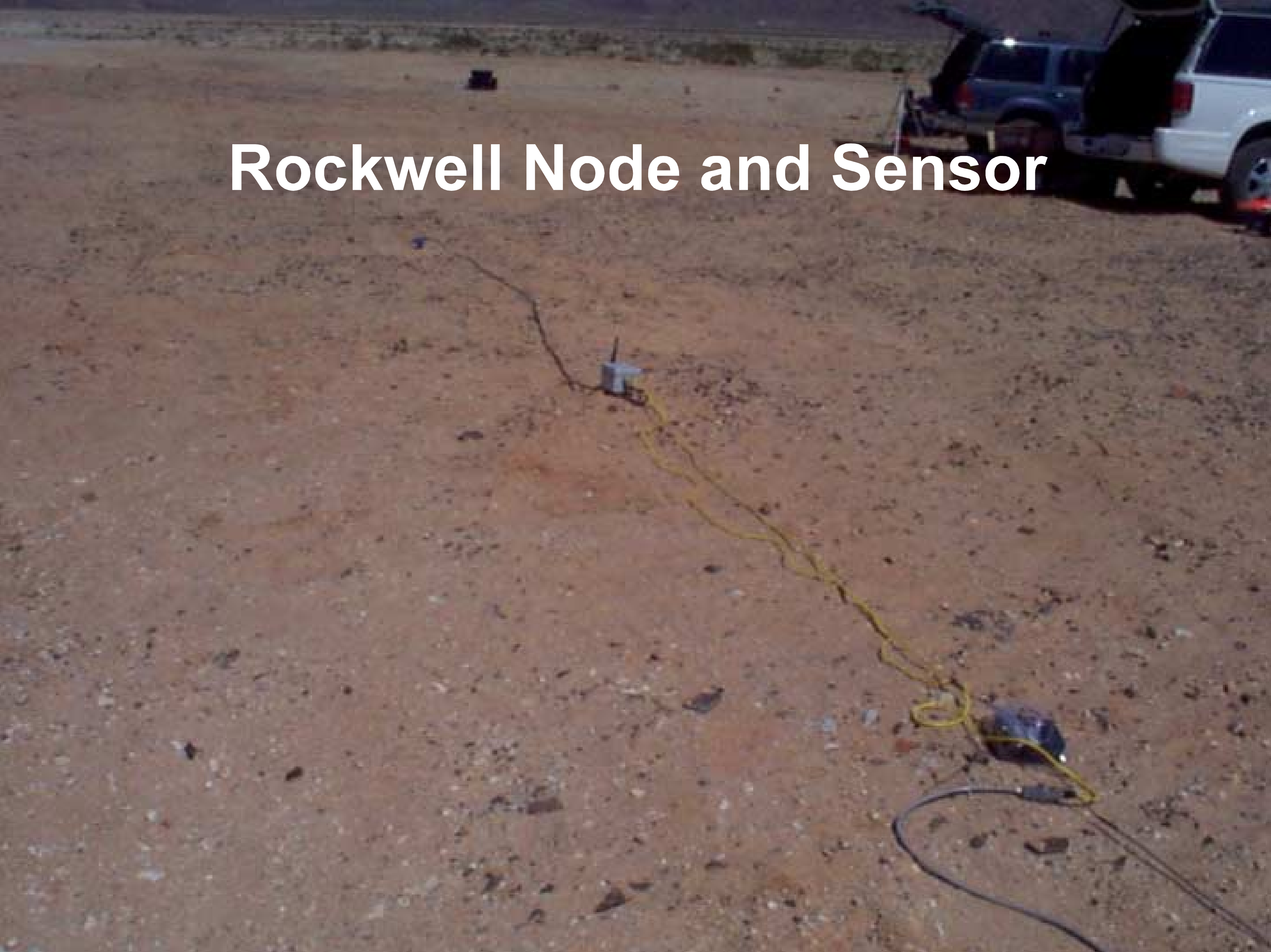
The UAV relayed this information to the base station on next over-flight.



Displays for Visitors at Base Camp


BAE/Sensoria Tracker/Imager

Sensoria Imager


Rockwell Node and Sensor

Rockwell Wireless Receiver

Rockwell Comm Link to Base Camp


Rockwell Cameras

Rockwell PDA Video

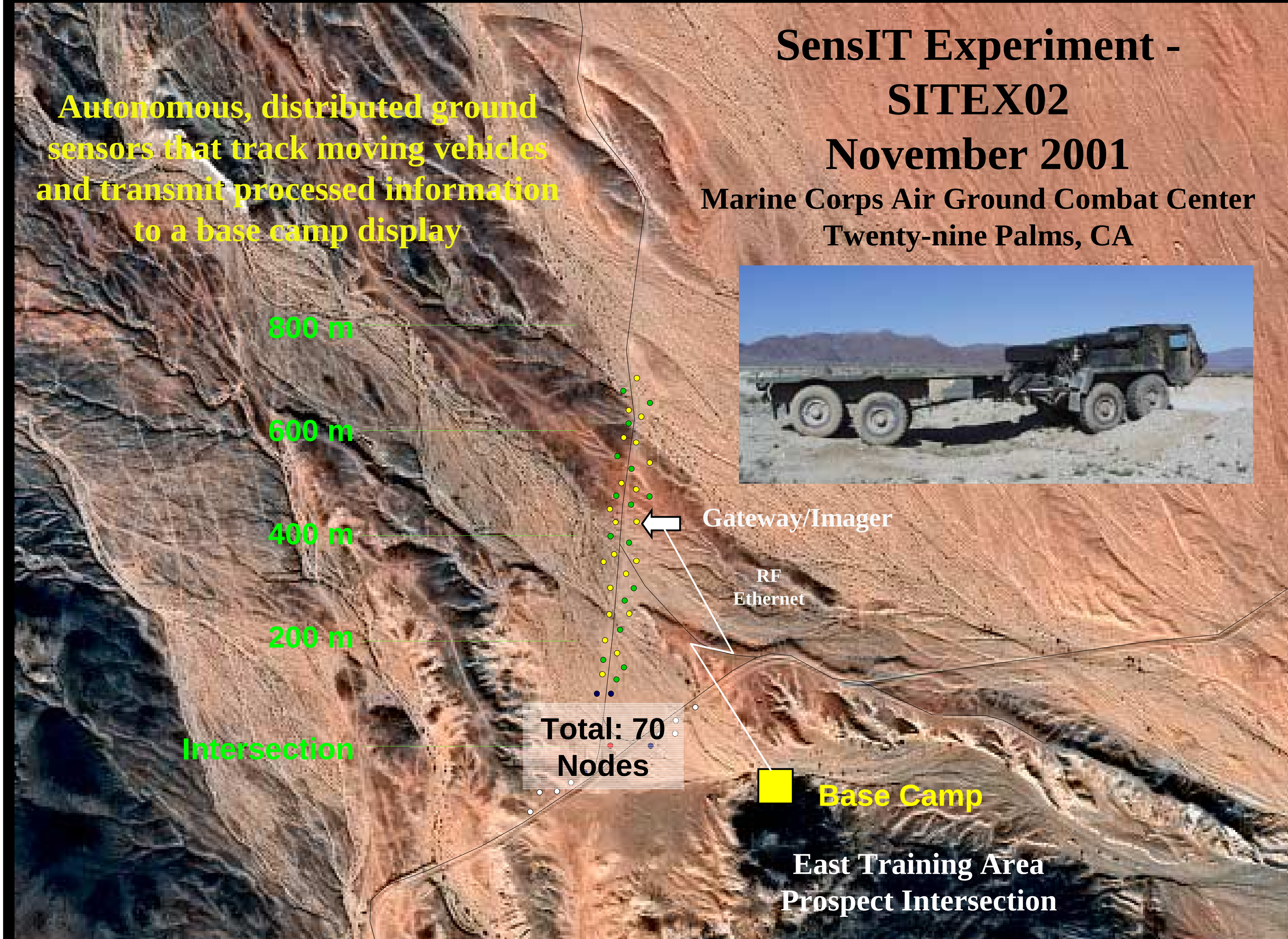

Berkeley Effort UAV

UAV Payload

UAV at Takeoff

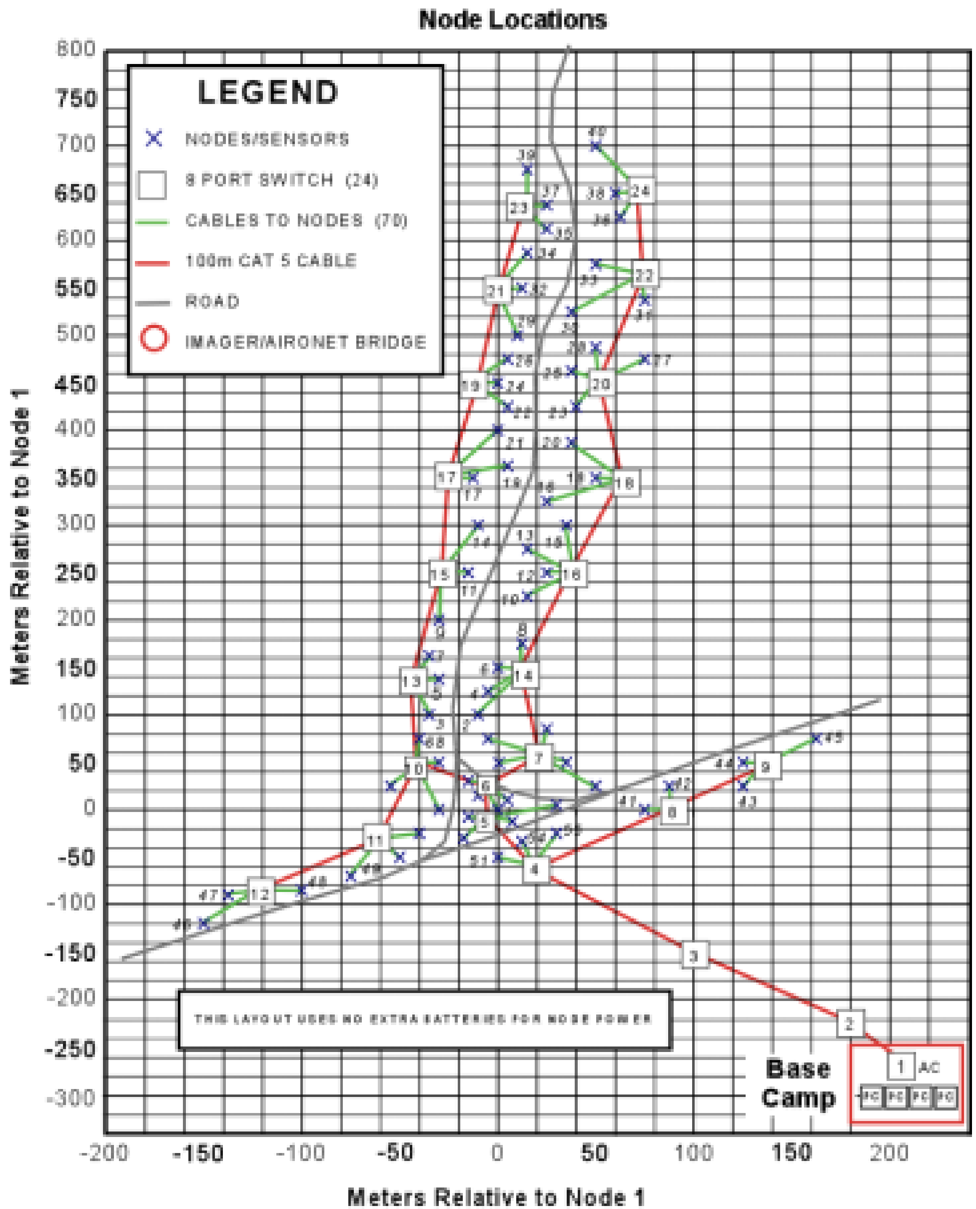

UAV Controller
PROPO
SELECT
CLEAR
XP8103


UAV Monitor



SensIT Experiment -
SITEX02
November 2001
Marine Corps Air Ground Combat Center
Twenty-nine Palms, CA
Autonomous, distributed ground sensors that track moving vehicles and transmit processed information to a base camp display
800 m
600 m
400 m
200 m
Intersection
Gateway/Imager
RF
Ethernet
Total: 70
Nodes
Base Camp
East Training Area
Prospect Intersection

The Deployed Network



Accomplishments

- Installed and operated in the field 70 dual-networked sensor nodes.
- Collected 30GB time series and event data
- Established and tested procedures
  - bringing node network up and down
  - initializing and operating an integrated set of processes on the Sensoria nodes
- Automatically triggered imager node using track projections calculated event detections
- Challenged WINS NG 2.0 nodes performance and reliability

SensIT Indoor Testbed

- BBN/Cambridge; Spring 2002
- Medium-scale network for API development, debugging, software integration and testing
- 20 WINS NG 2.0 Nodes + 2 Imagers
- Secure remote network access for PI testing and demo

Capabilities

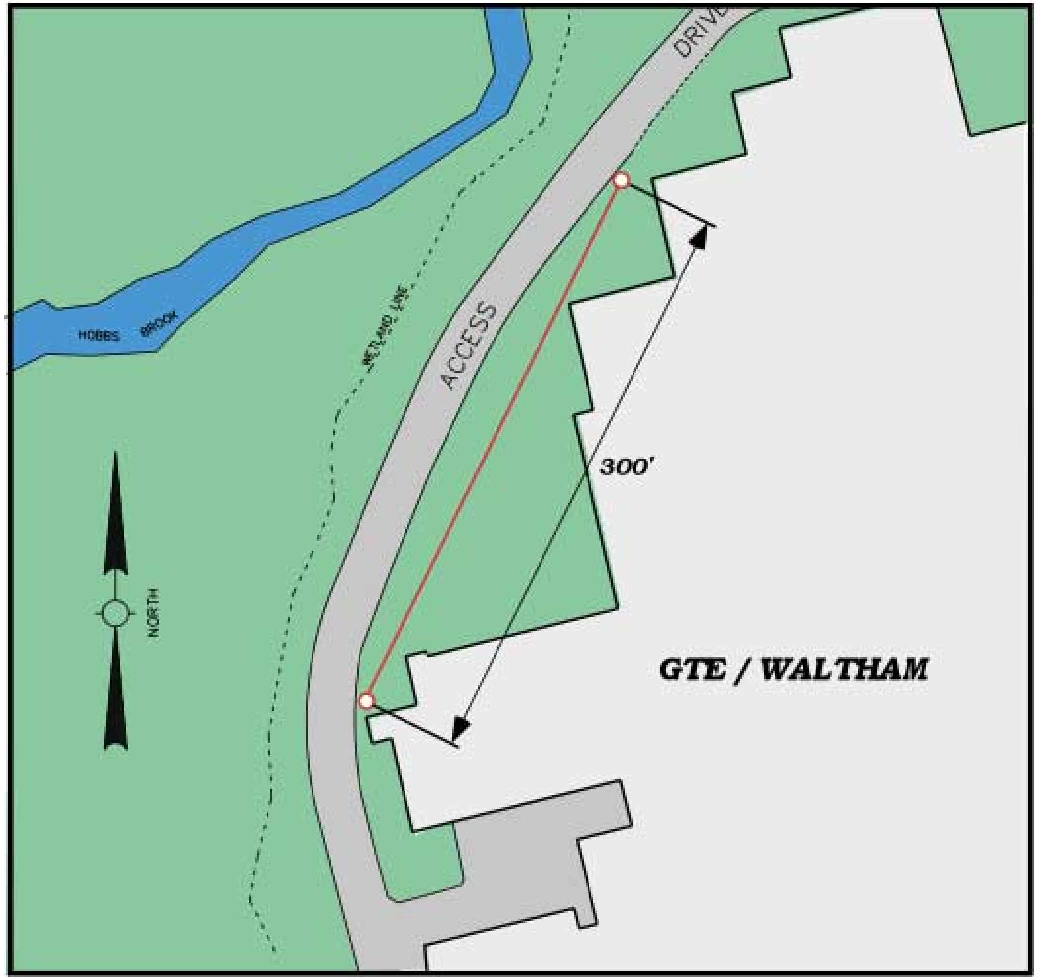
- Operation: 24/7
- Data sources:
  - Live PIR
  - Recorded event and time series playback (SITEX02 - 29 Palms)
- Comm.: RF and (private) ethernet

Testing

- Network Latency/Packet Loss
- Software upgrades
- Baseline Software Architecture
- GUI development
- Tracker Improvements

SensIT Outdoor Testbed - July 2002

Semi-permanent, medium-scale network for development, debugging, software integration and testing using real targets (non-tactical) or simulation



- 20+ WINS NG 2.0 Nodes
- Acoustic, Seismic, PIR
- Road Frontage: ~ 300 feet
- Adjacent office space
- Video Surveillance
- Operation: 24/7
- Secure remote access to nodes
- WINS RF and wireless ethernet comms
- Alternate laydowns available

Planned Testbed Activities

Major Events	July	September	November
Outdoor Testbed Setup	▲		
Data collection for vehicle counting	▲		
Single Vehicle Tracking Demo	▲		
Crossing Vehicles - Tests + Demo	——	—— ▲	
Convoy tracking - Tests + Demo	——	—— ▲	
Web-based GUI access		▲	
PI meeting in Mass.			▲
Capstone Demonstrations			▲ —— ▲