Why Harsh Environments

- Dense urban terrain represents the single most hazardous setting for engagement
- Casualty rate extremely high
- Increasing shift of world population to cities
  85% of world population by 2024
- GPS often ineffective
- Need to protect our forces, remove personnel from areas of high threat, deploy sensors & robots

- Other harsh settings: on ships, inside cargo containers, close to the ground...

UWB Claims

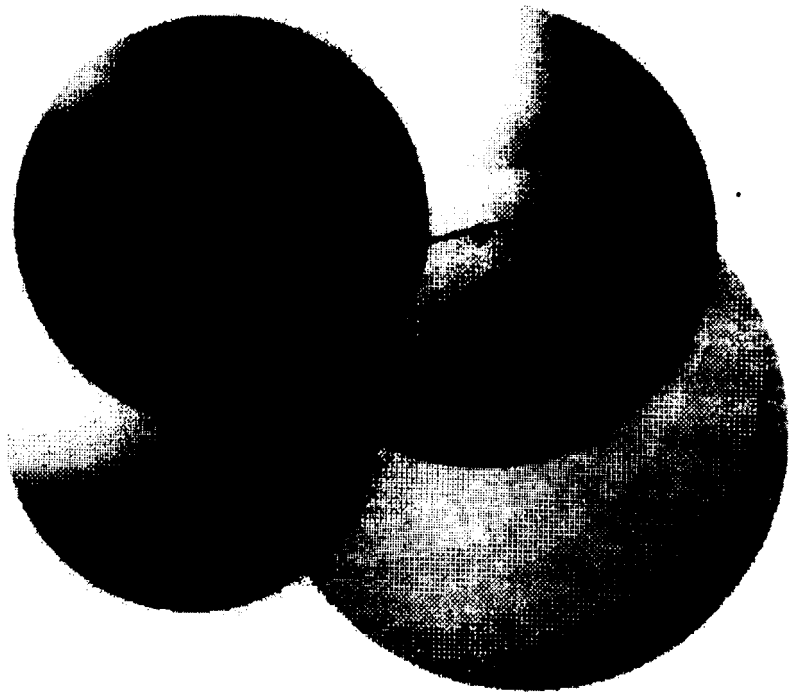
- No fading from destructive interference (coherent effects are less)
- Potential for single chip, all digital (cost savings)
- Lower power dissipation (few analog components)
- Built-in LPI/LPD/LPJ
- No need to get spectral allocation (uwb signal is buried in the noise)
- Penetration capability - walls, ground (enabled by low frequency component)
- High precision ranging (enabled by high frequency component)

- Focus on the real advantages of UWB
- Design and implement next-generation UWB hardware and software for ad-hoc networking in extreme environments.
- Develop uwb network-based geolocalization system
- Demonstrate key DOD applications in appropriately harsh, environments

Technical Areas

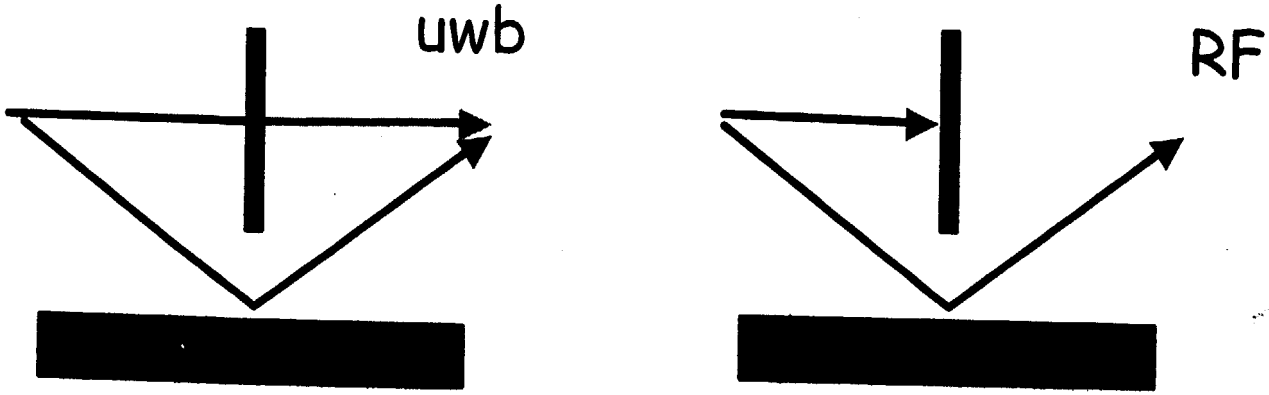
Precision Geo-Localization

- 3-D multi-lateration
- scalable and power-efficient geolocalization techniques
- in-depth tradeoff analysis
  (accuracy vs.
  power, number of nodes ..)
- mobility support



UWB Geolocalization Advantage

- GHz bandwidth gives sub-centimeter resolution
- inherent part of UWB networking node (no need for separate hw)
- smaller sensitivity to multipath delay ??



Bandwidth at lower frequencies gives penetrating ability
Direct path signal may be weaker,
but if detected, is used as first-arrival signal

Ultrawideband (Impulse Radio) Communications Technical Challenges

NETEX Industry Day

10 September 01

Dr. James A. Freebersyser
Program Manager, DARPA/ATO
(703) 696-2296
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Potential Advantages of UWB

- Ultrawideband Operation (> 1 GHz)
  - Better multipath fading performance (like any wideband signal would)
  - Large processing gain (> 40 dB) improves Anti-Jam (AJ) properties
  - Covert operation (Low Probability of Intercept/Detection (LPI/D))
  - Position location on the order of a few centimeters
- Greatly Reduced Power Consumption
  - Single chip (CMOS) implementation without mixed signal processing
  - Low duty cycle operation
  - Higher energy efficiency due to pulsed battery operation
- More Efficient Use of the Spectrum
  - More users per unit of bandwidth
  - Unregulated (FCC Part 15) operation
  - Reduced near-far interference resulting from low duty cycle operation
  - Full-duplex operation in the same frequency band

The Potential of UWB Impulse Radio Has Not Been Realized

Summary/Conclusion

- Ultrawideband - What's Old Is New Again!
  - Wireless could have gone straight to UWB if DSP had been available ☺
- A Cornucopia of Commercial and Military Applications
  - Communications, radar, geolocation, automation, measurement, etc.
- UWB Has The Potential for Revolutionary Change
  - Regulatory changes (FCC Part 15?) are needed
- UWB Research Has Only Just Begun
  - Propagation, antennas, circuits, devices, waveforms, signal processing, radio architectures, MAC/network protocols, etc.

Ultra Wide Band Applications and Requirements

DARPA NETEX Industry Day
McLean, VA

10 Sept 2001

Steven J. Gunderson
NFESC Port Hueneme

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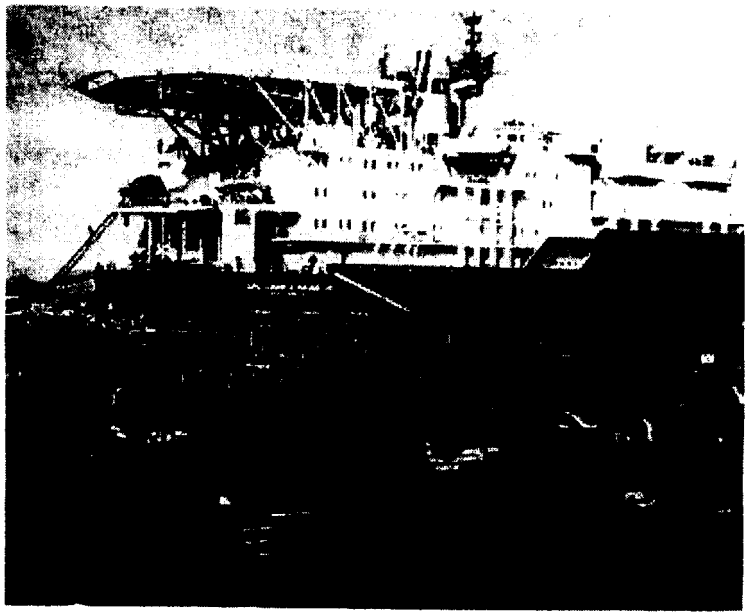
NEF
Obj

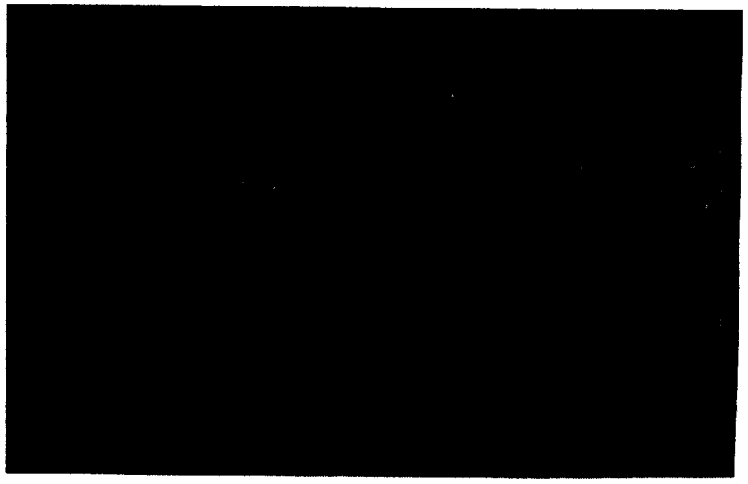
UWB Applications: Logistics

Desert Storm

- **First MRC with ISO Containers**
  - 40,000 Containers, Opened 25,000
    - » Paper Manifests Were Inaccurate and Easily Lost
  - ISO Containers Hid the Stuff
    - » Previous MRCs Used Break Bulk
  - Misplaced & Lost Stuff = $3 Billion
    - » GAO Report B-246015, Dec 1991



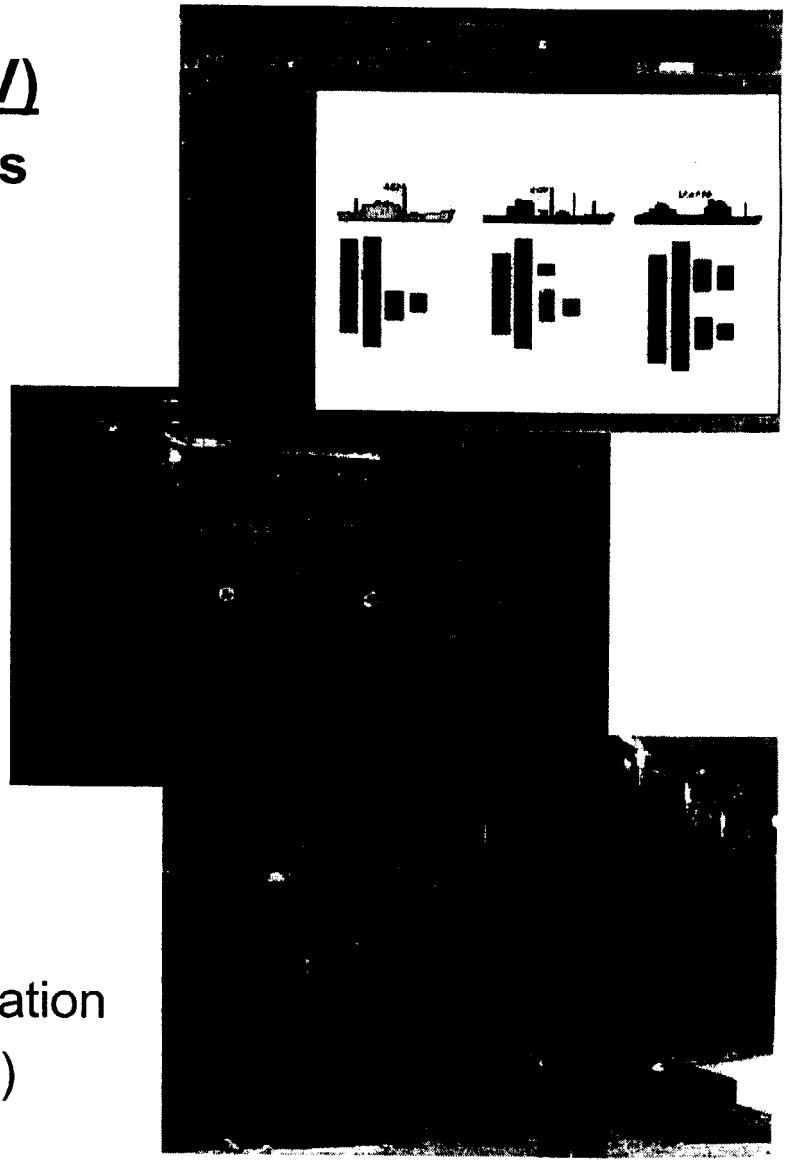
- **The BIG Questions**
  - What Do I Have?
  - Where Is My Stuff?
  - What Is In the Box?
  - What Is Its Condition/History?



UWB Applications: Logistics

Naval Total Asset Visibility (NTAV)

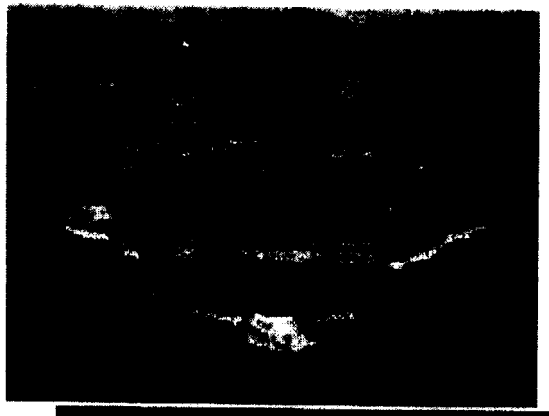
- **Tackle the Unsolved Hard Problems**
  - Precision Asset Location (PAL)
    - » Where's my Stuff?
    - » Ship Stow Plans
      - 40% Stow Error, Re-Inventory Required
  - Autonomous Manifesting (AM)
    - » What's in the Box?
    - » The "Holy Grail of Logistics"
  - Infrastructure Reduction (IR)
    - » Cost Reduction ($K's/Reader)
    - » Ship Pre-Installation and Cabling
- **Transportation is a $1T Industry**
  - DoD is Largest Purchaser of Transportation
  - US CINC Transportation (TRANSCOM)

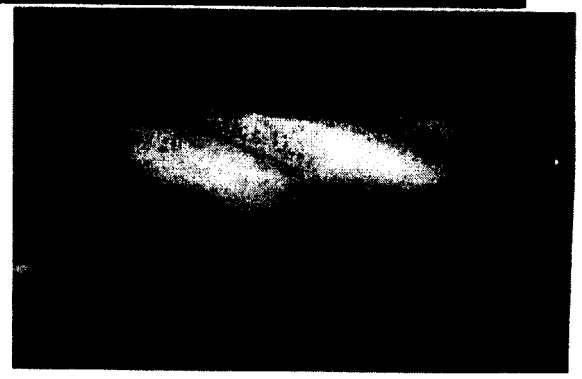


UWB Applications: Weapons

Carrier Weapons Management

- **NAVAIR / NAWC Lakehurst**
- **Problem**
  - Aircraft Leave With Partial Loads
    - » Desert Storm: Several Carriers Continuously Launched Aircraft with 2 or Less Weapons
  - Locate Weapon Components for Assembly
    - » Up to 9 hrs for Assembly: 8 Decks, 32 Mags
  - Locate Weapons in Hanger & Flight Decks
    - » Staging Areas, Main Deck, Bomb Farm
- **Hot RF Spots Throughout Carrier**
  - High Powered Radars: EMI / EMC / HERO
- **Proposed Solution**
  - UWB Precision Location of Weapon Sleds: 1 ft
- **Makes Aircraft Carriers More Lethal**

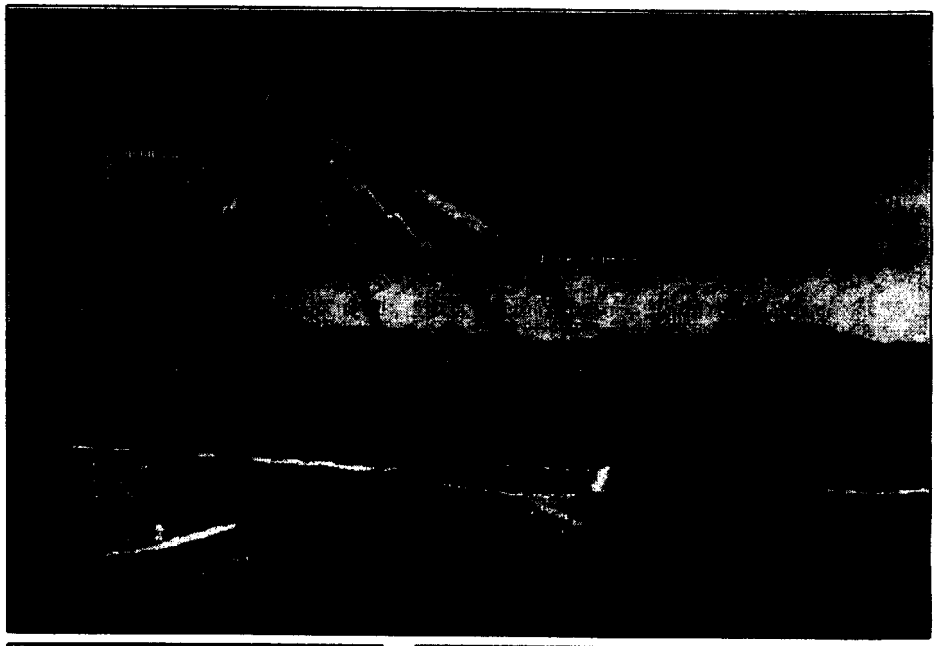


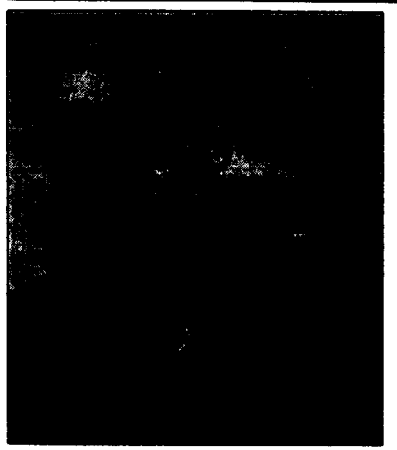


UWB Applications: Geolocation

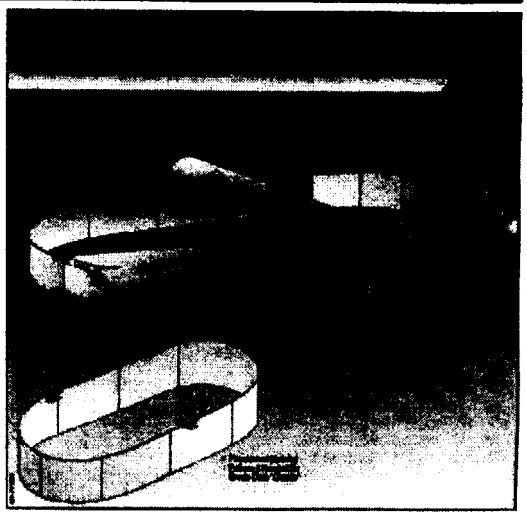
UAV Landing System

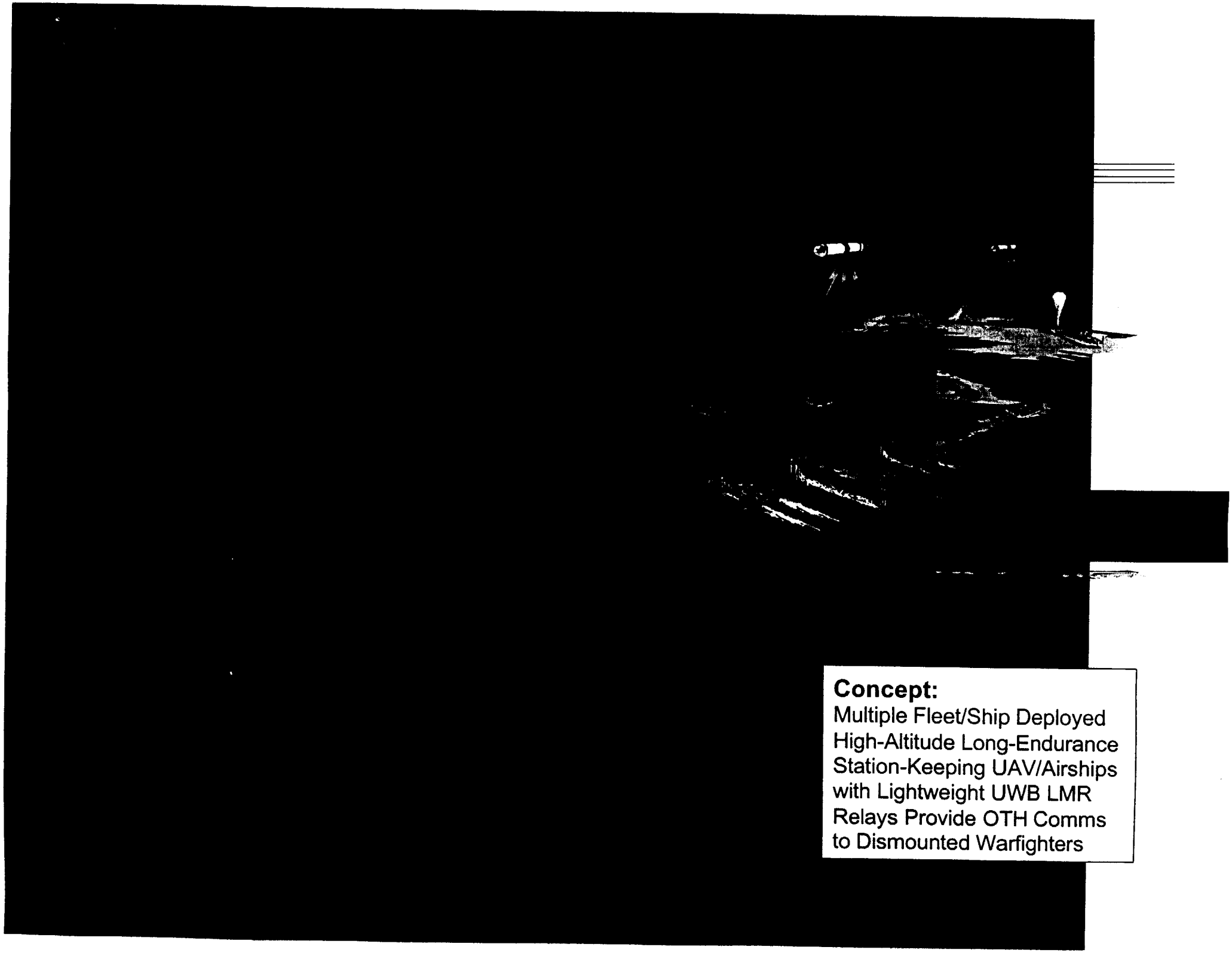
- **UAV Common Automatic Recovery System (UCARS)**
  - Pioneer UAV
  - Microwave: 3 ft Accuracy
  - 6 ft Landing Grid
    - » Pitch / Roll / Stability
    - » Ship Under Way
- **RQ-8 Vertical Takeoff UAV**
  - 3 hrs 150 nmi, 12 hrs Total
  - Payload Capacity = 300 lbs
  - Comms Payloads
    - » (3) ARC-210 (Aircraft Radio)
    - » TCDL: 14-15 GHz, 10 Mbps
    - » SINCGARS to Ground MEUs





UCARS Ldg. Sys.



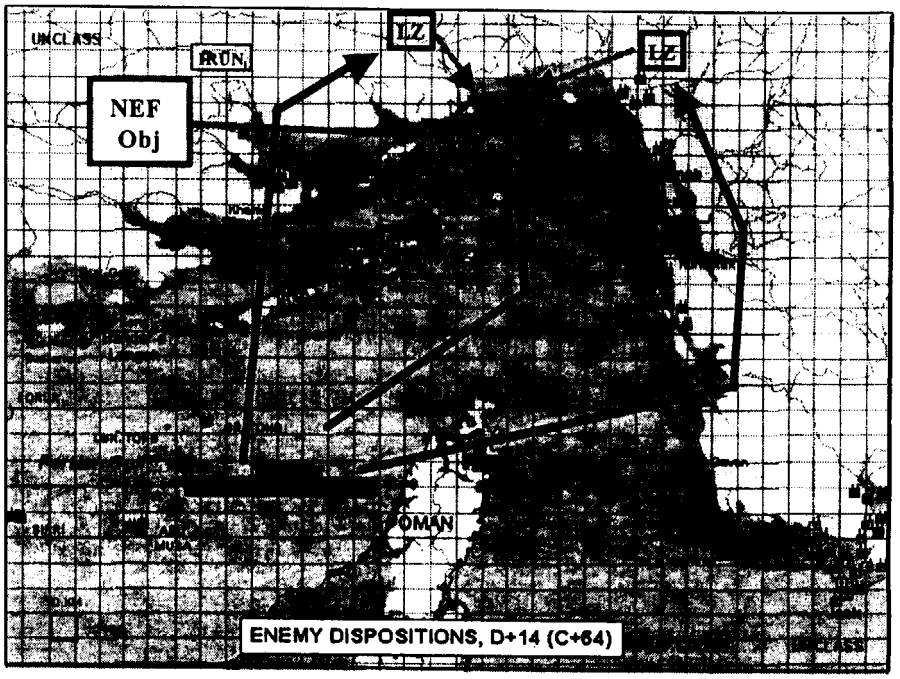


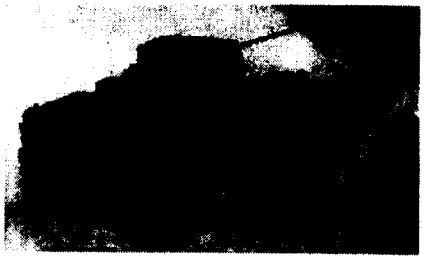
Concept:
Multiple Fleet/Ship Deployed High-Altitude Long-Endurance Station-Keeping UAV/Airships with Lightweight UWB LMR Relays Provide OTH Comms to Dismounted Warfighters

UWB Applications: Comms

Marine Corps OMFTS/STOM

- **High Capacity LOS Comms**
  - Replace MRC-142
    - » 576 Kb Ship-to-Shore, 25 nm
    - » Losing 1350-1850 MHz Band
- **Command Post on the Move**
  - Secure Wireless LAN
    - » Connect Servers Within CP
- **Convoys on the Move**
  - Inter-Vehicle Comms
- **Combat ID**
  - Geolocation
  - Surface Management
    - » Ship-to-Shore Movement: AAAV & LCAC
- **Asset Visibility**

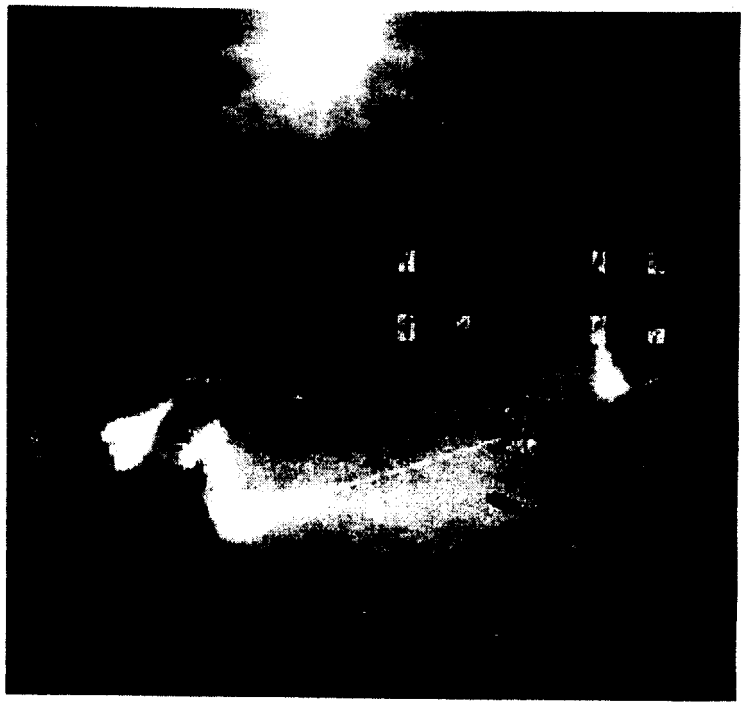


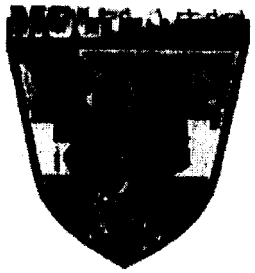


UWB Applications: Comms

Urban Warfare

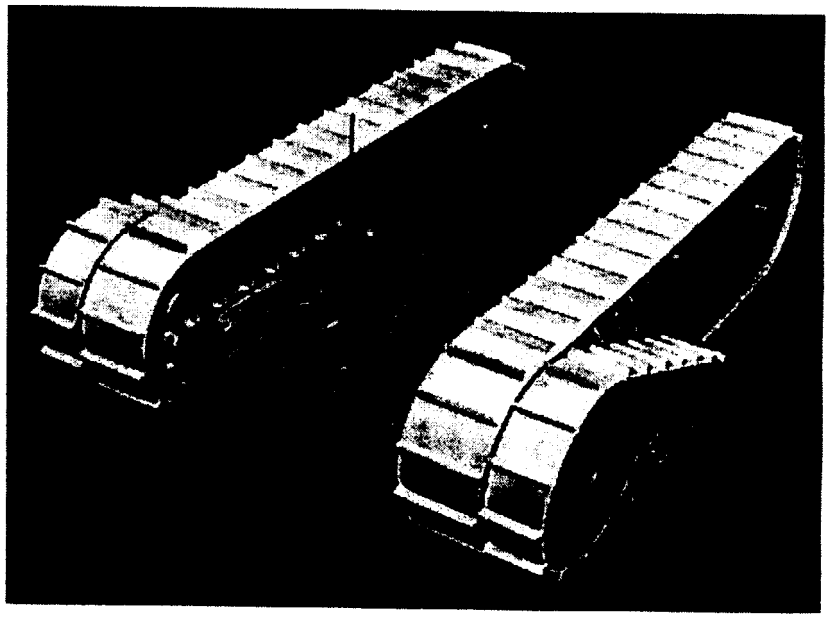
- **MOUT ACTD / USA / USMC**
  - Frustrated Requirements: **C4I**
    - » R1: Identification of Friendly, Enemy, Noncombatants (IFF)
    - » R3: Hands-Free Non-Line of Sight (NLOS) Communications
    - » R7: Thru-Wall Sensing
    - » R41: Position/Location Inside Buildings
  - Military/Com'l Comms Inadequate
    - » Marine Corps Inter-Squad Radios (ISR)
      - ICOM UHF Radios: Non-Secure - 16,000 Units
    - » Need Secure Radio, 1-5 Km Range
      - PRC-126 Size, Light Weight (Micro-UAV)
      - C2 for Unmanned Ground Vehicles & Video
  - Transition to Proposed Vanguard ATD '03
  - Transition to SBCCOM Objective Force Warrior Program





UWB Applications: Comms

Tactical Mobile Robots (TMR)

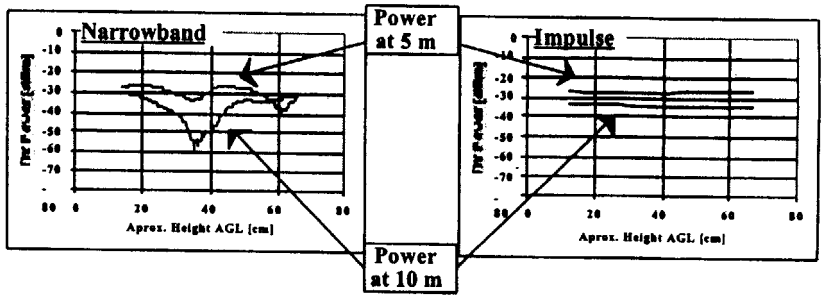


- **Imperatives**
  - Tele-Operation
    - » C2, Audio and Video
    - » Robots Talk to Each Other
  - Geolocation / Navigation
    - » Robots Find Each Other
  - Autonomously Reestablish Comms
- **Requirements**
  - Bandwidth
    - » C2 & Audio (low latency) 25 Kbps
    - » Video (B&W, fuzzy, min) 100 Kbps
    - » Color Video (160x120) 1-2 Mbps
    - » High Res Video (320x240) 3 Mbps
  - Range
    - » 500m min (LAN Block Conv), 1-2 Km
  - Weight & Power: 1-2 lb, 2-5 W
  - Geolocation: 1 cm
    - » Navigation/Mapping/Marsupial
  - Environment
    - » Urban: Streets, Buildings, Sewers, Tunnels
    - » High EMI: DC Motors

UWB Requirements

Advantages

- **Multi-Path**
  - Minimize Nulls in Urban Environments
  - $1/r^2$ -- $1/r^4$ -- $1/r^6$ Losses
    - » 1 - 2 Orders Better than Narrow Band
      - Extra Transmitter Power Not Needed: 10-100X



- **Co-Interference**
  - FHSS: SINCGARS -- >2.5 Radios Co-located
  - DSSS: Near-Far Power Management -- Qualcomm 1 dB Match Required
  - UWB: 40-50 dB Rejection
- **Land Mobil Radio (LMR) / Cellular**
  - Greater Agility: No Critically Tuned Tanks / Combiners / Splitters
  - No Dedicated Reservation Channel
- **Interceptibility**
  - Inherent LPI/LPD/LPE/AJ
- **Geolocation**
  - High Inherent Accuracy: Short Pulse Length ~1 ns = 1 ft
- **Dual Capability: Communications and Geolocation Simultaneously**

UWB Requirements

Architectures

- **Voice**
  - Inter Squad Radio (ISR)
  - Land Mobile Radio (LMR)
- **Data**
  - Burst Store & Forward
  - TCP-IP / Packet
  - Ad-Hoc Peer-to-Peer Networks
- **Video**
  - High Data Rate 1-3 Mbps
- **Geolocation**
  - Intra-Squad
  - Urban: Bldgs, Streets, Sewers
  - Alternate GPS

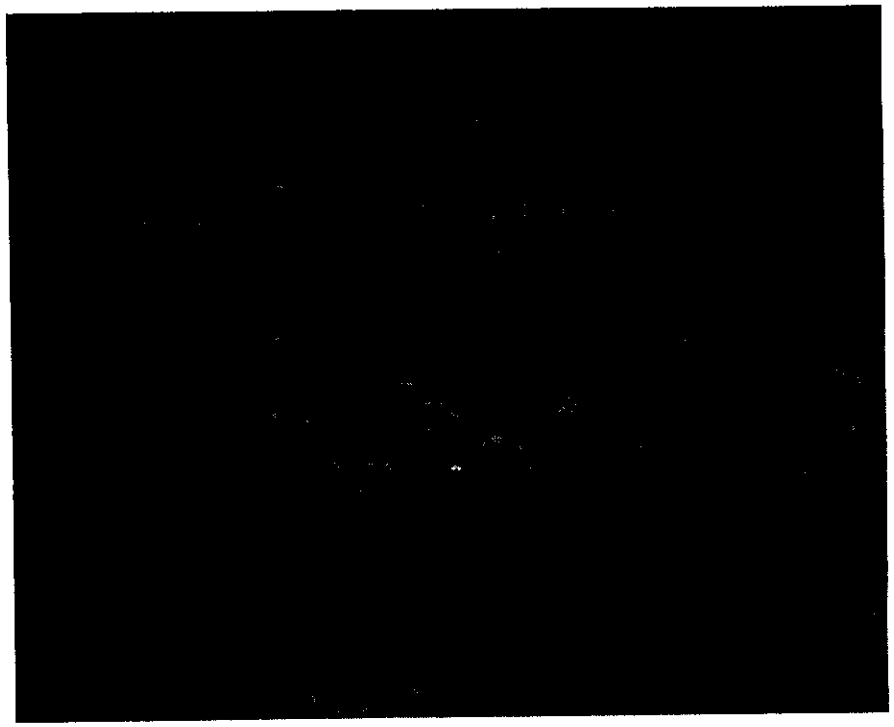
Warfighter Requirements

- **Works Anywhere**
  - Urban
  - Triple Canopy
  - Mountain Terrain
  - No Terrestrial Infrastructure
- **Quality**
  - Fast Enough
  - Secure: LPI/LPD/LPE/AJ
  - 20 - 30 dB More Link Margin
- **Logistics**
  - Small
  - Light
  - Cheap

Conclusion

Hunter Warrior AWE

- **Marine Corps Warfighting Lab**
  - First AWE, 1997 All Data
  - RMA: Asymmetrical Warfare
- **DARPA Provided Technology**
  - Land Mobil Radio (LMR)
  - Internet Node In the Sky (INITS)
  - Shared Net: *Content Centric*
  - ADOCS / LeatherNet (M&S)
  - Surrogates, But They Worked
- **Burst Store & Forward**
  - LMR: Serial, 2.7 Kbps
    - » Short Message: OTH Gold & VMF
    - » 3 Sec on Air, Hard to Locate
  - INITS: TCP-IP, 300 Kbps Total



"In This World Where We're Carrying **Mobile Handsets**, I'm Afraid the Communications of the World's Most Advanced Military Are Operating at Levels that are 40 Years Out of Date."

Adm. Owens (ret)