CERDEC Contributions to Army Battle Command Networking Efforts

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Evolution of Army Networking

**Civil War**
- U.S. Army Signal Corps (1860)
- Telegraph

**World War I**
- WWI Pigeon, Mockers
- Clark Portable Army Radio Set (1906)

**Vietnam**
- PRC-77
- PRT-4 & PRR-9
- WWII Radios

**World War II**
- United States Army Pigeon Service
- PRC-6

**1980s-2006+**
- MSE
- Manpack UHF SATCOM
- SINCGARS
- EPLRS

**2014 BCT Architecture**
- Tactical Internet
- SINCGARS
- Other Services
- Strategic Network
- M2E Packet Network
- Mobile Ad Hoc Network
- Gateway

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Major Communications Thrusts

- Mobile Networking
- Antennas
- Information Assurance

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## Comparison of Commercial & Military Communications Architecture

### Commercial
- Mobile Subscriber, Fixed Infrastructure
- Pre-configured Networks
- Tall, Fixed Antenna Towers
- Fiberoptic Internodal Connections
- Spectrum Availability
- Fixed Frequency Assignments
- Protection: None ☰ Privacy (single level)
- Interference Rejection is Somewhat Important
- Low probability of Detection (LPD) is not an issue

### Military
- Mobile Subscriber - Mobile Infrastructure
- Ad Hoc, Self Organizing Networks
- Small, Easily Erectable Masts; Low Profile OTM Antennas
- Mobile, Wireless, Internodal Connections
- Restricted Frequency Assignments; Geographically Impacted
- Protection: None ☰ Top Secret/ SI (Multiple, Simultaneous Levels)
- Interference Rejection and Antijam are Critical
- Low Probability of Detection (LPD) is Critical

### Strategy
- **Adopt**
- **Adapt**
- **Modify**
- **Develop and/or Influence**

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Applied to Customers Requirements:
- FCS BW for BC
- FCS Voice Architecture Study
- FCS Network Assumptions Whitepaper
- Tactical Network Ground Forces Study
- Etc….

SE Process

- Lessons Learned
- Technology Transition Agreement
- Critical Technical Elements
- Critical Program Information Assessment
- Critical Design Review
- Critical Program Information Assessment
- Simulation Plan
- Experimentation Plan
- Technology Protection Plan
- Technology Readiness Level Assessment
- Technology Readiness Level Assessment
- Prototype
- Final Design
- Field & Experimental Testing/Evaluation
- Data Collection
- Emulation

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Technology Development and Maturation

User Needs & Technology Opportunities

• Process entry at Milestones A, B, or C
• Entrance criteria met before entering phase
• Evolutionary Acquisition or Single Step to Full Capability

A
Concept Refinement

B
Technology Development

C
System Development & Demonstration

Design Readiness Review

Pre-Systems Acquisition

LRIP/IOT&E

Systems Acquisition

FRP Decision Review

Production & Deployment

Operations & Support

Sustainment

IOC

• Process entry at Milestones A, B, or C
• Entrance criteria met before entering phase
• Evolutionary Acquisition or Single Step to Full Capability

Validating TRL’s & Supporting POR’s Milestone Decisions

TRL 1-3

TRL 4-6

TRL 7-9

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Seasoned team of subject matter experts & analysts

Warfighters and scientists working side by side

Seven years of field experimentation experience

SoS engineering processes & procedures – rapid prototyping frameworks

- R&D **venue** offering the **Tech Base** and **Programs of Record** a **continuous** and enduring **evaluation** capability for Network Centric Warfare (NCW) concepts
- Conducts Live, Virtual, and Constructive **technology demonstrations** currently supporting scales on the order of **100 live and 3,000 virtual/constructive entities**
- Provides a **relevant environment** to assess emerging technologies in a C4ISR **System-of-Systems (SoS)**
- **Mitigate risk** for FCS Concepts, Future Force technologies
- Opportunities for **acceleration of technology insertion** into the Current Force
- Venue for **validation of Technology/Software/ Integration Readiness Levels**
- Includes a **state-of-the-art instrumentation, data collection & reduction** (IDC&R) tool suite that supports the quantification of NCW activities
- Employs system of systems engineering methods that promote **rapid SoS reconfiguration** and enable repeatable assessments
- Has a diverse set of experience over the past seven years in working with dozens of government and industry partners to **integrate and execute large-scale, distributed Live/Virtual/Constructive events**
## Technical Metrics

**C4ISR System Performance**
- Network Connectivity
- Message Completion Rate
- Probability of Detection
- Probability of Identification
- Detection Accuracy
- Power Usage
- Visualization Resolution

## System Knowledge

**Quality of Information**
- Accuracy, Completeness & Timeliness of Information about Threat
- Level of Situational Awareness Achieved
- Number and Types of Decisions Made

## Operational Metrics

**Soldier Unit Performance**
- Time to Execute Mission
- Blue Losses
- Red Losses
- Degree of Surprise
- Ability to Maneuver Undetected
- Number of PIR Satisfied

### Quantifying How Technical Performance Impacts Operational Effectiveness

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Support to PM Programs and Tech Base Efforts

PM WIN-T 2007 Increment 2 Engineering Field Test
- Critical Technology Elements
- Network Scalability

JTRS SLICE SRW 2006/7 Technical Field Tests
- Waveform maturation

PM FCS 2007 Technical Field Tests
- SUGV Teleoperation
- T-UGS / U-UGS
- NEBC Technology Transition

Natick Soldier Center 2006/7 Future Force Warrior
- Exit Criteria Testing
- Transition to PEO Soldier

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• Tactical Wireless Network Assurance
  - Black Side Intrusion Detection system

• Soldier Radio Waveform
  - Mobile AdHoc networking for Soldiers, sensors, munitions

• Command and Control of Robotic Entities (C2ORE)
  - UAV mission planning and execution software autonomously controls multiple UAVs
  - Enhances planning and management of unmanned sensor assets (UGS, UAV, UGV, etc)

Body Wearable Antenna Technologies for SRW

2 Port Low Profile Antenna for Wideband Networking Waveform (WNW)/ Soldier Radio Waveform (SRW) bands

Antenna optimization Modeling and Simulation for Command & Control Vehicle (C2V) and Reconnaissance & Survivability Vehicle (R&SV)
The Soldier Radio Waveform is a mobile, ad-hoc, networking waveform developed and transitioned to provide improved voice and data communications, for platforms with Size, Weight, and Power constraints. Hosted on Joint Tactical Radio Systems (JTRS) Handheld Manpack Small Form Factor (HMS) and Ground Mobile Radio (GMR).
Antenna M&S Performance on Vehicles Process

Antenna Model Validation
- Anechoic Chamber Measurement
- xFDTD Antenna Model
- Overlay Result

Platform Model Validation
- Actual Vehicle
- Vehicle CAD Model
- xFDTD Electromagnetic Meshed Model

Finite Difference Time Domain (FDTD) Simulation
- 360° Far-Field Antenna Gain Pattern

Geometrical Theory of Diffraction (GTD) Simulation

Vehicle Model with Validated Antennas

Hybrid M&S Results

Power Contour Plots

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Example: MRAP Antenna Placement Optimization

SPAWAR Recommended Location

Poor Pattern

CERDEC M&S Placement with Optimized Pattern

115 Antenna Base @ 2 meters Above Earth Ground

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Purpose:
• Develop Affordable, Low Profile Solutions For OTM SATCOM
• Develop Affordable Directional Antennas for Terrestrial Directional Networking
• Develop Omni-directional Antennas With Higher Gains, Lower Profiles with Ballistic Radomes, and Multiple Ports to Reduce the Number of Platform Antennas
• Develop Integrated Antennas for Dismounted Soldier
• Develop Distributed Antennas to Improve Omnidirectional Antenna Performance and Reduce Cosite Interference

Products:
• Low Cost Ku/Ka Band OTM SATCOM Antenna Systems
• Low Cost X-band Point Of Presence
• Efficient Ku and Ka Band Power Amplifiers
• Low Profile Single Beam Ku/Ka SATCOM Ant System
• Low Profile Multibeam Ku/Ka/Q SATCOM Ant Analysis
• Affordable Terrestrial Directional Antennas
• WNW High Gain Omni Antennas
• 2-Port Low Profile Omni Antennas with Ballistic Radome supporting multiple waveforms (Ground/RW)
• 3-Port Tri-band Omni Antennas
• Integrated Body Wearable Antennas
• Distributed Antenna Array

Payoffs:
• Affordable OTM SATCOM and Terrestrial Directional Ants.
• Reduced Visual Signatures & Antenna Counts
• Improved Link Connectivity and Ballistic Protection
• Reduced Platform Power Consumption
Purpose:
- Develop, mature, and demonstrate low profile antennas for directional and satellite communications (SATCOM) on-the-move (OTM)

Products:
- Low-profile, single-beam (Ku/Ka) antenna
- Low-profile, multi-beam (Ka/Q) antenna
- Single-beam high capacity communications capability (HC3) (Ka/Q) antenna
- Small aperture blue force tracking (BFT) antenna
- C/Ku Affordable Directional Antenna
- Integrated Ka/Q-band Power Amplifier

Payoff:
- Increased Communications Capabilities at all echelons through greater use of SATCOM OTM
- Reduced platform burden through reductions in antenna size, weight, and power (SWaP)
- Increased survivability through reduced visual signature
- Affordable SATCOM OTM for the warfighter through antenna cost reductions

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
**Purpose:**
To develop and transition wireless network protection solutions for a tactical Mobile Ad-hoc Networking (MANET) environment that is typical of WIN-T and the Future Force.

**Product:**
- Tactical security administration tool for mobile wireless environment.
- Intrusion Detection Algorithms for MANET routing protocols
- Tactical Public Key Infrastructure (TPKI)
  - Architecture
  - Certificate Issuance
  - Field Replacements
  - Revocation

**Payoff:**
- Prevent threat Information Warfare attacks from damaging mobile networks.
- Maintain Warfighter trust/confidence in battlefield information.
- Reduce system and network vulnerabilities.
Purpose:
Develop and transition software and algorithms that tailor and manage the flow of Battle Command (BC) information and C2 services between current and future systems throughout all phases of operations and environments.

Products:
• Battle Command Planning/execution/re-planning products for:
  – Dismounted applications in Complex and Urban Terrain
  – Current Force Tactical C2 Systems
  – Unmanned systems and sensors
  – Decision support tools that account for political, religious, cultural and other factors

• Managed Connectors that govern the flow of information between disparate architectures while globally managing resources

Payoff:
• Increased speed/quality of BC planning and execution adjustments
• Improved commanders’ understanding of Battlespace and related factors
• Faster decision-making

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Purpose:
- Develop Soldier Radio Waveform (SRW) for Dismounted Soldier and manned & unmanned systems.
- Develop communications and networking technologies that address Future Force constraints for bandwidth and connectivity while on the move.

Product:
- JTRS Software Communications Architecture (SCA) v2.2 compliant, energy-efficient Soldier Radio Waveform (SRW)
- PILSNER Proactive Diverse Link Selection (PAD-LS) algorithms to enhance OTM connectivity and capacity
- Faster than real time dynamic link estimation for connectivity and capacity for Network Management and man in the loop experimentation

Payoff:
- Energy efficient voice & data tactical communications for Ground Soldier Systems/Future Force Warrior and sensor-to-shooter linkages
- Increased OTM connectivity and usable bandwidth
- Enable commanders to plan communication coverage for OTM Coarse Of Action (COA)
- Addresses PM FCS (BCT) Critical Technology #7B (SRW), Risk #93 mitigation (SRW Availability) to support “Network Ready”
**Purpose:**
- Develop, mature, and demonstrate modular tools and technologies that significantly improve the network planning and management of the tactical network.
- Develop, mature, and demonstrate security tools to protect mobile networks from attacks and allow information to be shared across security domains.
- Develop, mature, and demonstrate agent enhanced Battle Command (BC) tools to enable real time situational awareness and relevant strategic and tactical battlefield information sharing.

**Products:**
- Automated Network Management (NM) Tools
- Information Assurance (IA) Tools
- Space/Strategic and Tactical Information Dissemination and Management (ID&M) Applications and COA development

**Payoff:**
- Reduce manpower and network management configuration time.
- Share information across security domains while ensuring trust/confidence in information being sent to the Warfighter.
- Improve information sharing by providing relevant information from strategic to a tactical operational unit.

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• Affordable Satellite Antennas for Transformation Comm Systems
  – On The Move Multi band, single/multi beam
  – Affordable phased array antennas

• Advanced Wireless Security Services
  – Integrated Information Assurance (IA) Correlation and Response
  – Software Cross Domain Security Services

• Cognitive Networking
  – Multi-Function RF systems (Radio / EW)
  – Dynamic Spectrum Access Capabilities
  – Adaptive middleware for applications to adjust to network conditions.
Disciplined Systems Engineering Approach

- Dynamic Spectrum Process & Sensing
- Networking
- Data Exchange & Dissemination
- Information Assurance
- Applications
- Cognitive Management
- HW Design & Development
- Cross Layering
- System Evaluation

Current Knowledge base Inputs: DARPA, Industry, ARL, Etc...

Simulation/Emulation → Development Of Prototypes → Testing/Demos

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
**Description:** A cognitive network consists of technologies that can perceive current network conditions, and then sense, plan, decide and act on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end performance goals and user needs.

**Benefits:** A cognitive radio has awareness of changes in its environment and adapts its operating characteristics to improve its performance or to minimize a loss in performance.

**Generic Cognitive Processing Framework – An Example**

![Diagram of the generic cognitive processing framework](image)

- **Reflective**
- **Deliberative**
- **Long Term Memory**
- **Reactive**
- **Perception**
- **Action**

**Environment**

- **Control and Configuration**
- **Down-conversion, Up-conversion, Frequency translation, channel filtering, sampling, error correction, channel estimation, demodulation, modulation**

**Increasing Use of Software**

- **USR**
- **ISR**
- **SDR**
- **SCR**
- **HR**

**HR – Hardware Radio**
**SCR – Software Controlled Radio**
**SDR – Software Defined Radio**
**ISR – Ideal Software Radio**
**USR – Ultimate Software Radio**

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Example: Cognitive Radio

Benefits

Current Radio Architectures
- Extensive planning before deployment
- Detailed organization structure required accounting for every radio
- Detailed definition of Comm. Circuits and static routing procedures
- Intensive training for network development
- Static Network Configuration
- Limited network adjustment
- Individual nodes unaware of conditions experienced by other nodes
- Unaware of context of operation

Future Cognitive Radio Architectures
- Automated Policy Planning
- Policy Adjustment Based on Needs
- Less “Knobs” for the Warfighter
- Lessens training required for operators
- Decisions made to meet requirements of user with minimal interaction
- Variable network configurations in real-time
- Automated response fostering optimum network performance
- Learning from user experiences in entire network to adjust goals
- Automatic adaptation based on changing context

Legacy Example: EPLRS
Numerous Planning Steps Before Deployment

Bottom Line: Adaptable and Ease of Use for the Warfighter

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Questions?