Army Network Science

NDIA

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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• The power, promise, and ubiquitous nature of networks

• The science of networks is a key to Army transformation

• Army Network Science
  - Key Initiative
  - Supporting Programs
Networks
The fundamental components of a network are its structure (nodes and links) and its dynamics, which together specify the network’s properties (functions and behaviors).

Science
Core research principles which enable predictions of behaviors, given structure and dynamics as inputs.

Networks Science
The study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena.

http://fermat.nap.edu/catalog/11516.html
ASA(ALT) commissioned
Examples of Complex Networks

- Internet
- Power grid
- Transportation
- MANET (FCS Brigade Combat Teams)
- Social (friends, tribes, organizations, towns, cities, countries, global village)
- Insect (bees, ants, wasps and other swarms)
- Ecosystems
- Cellular (neuronal)
- Molecular (metabolic)
Characteristics of Networks

Robustness

- Redundancy -- duplicate pathways create a simple form of robustness
- Recurring circuits -- negative feedback for stability and tracking; positive feedback for enhanced sensitivity
- Modularity -- encapsulation of functions into simpler units yields better failsafe designs
- Hierarchies and protocols -- distributing functionality across different levels in the network to manage complexity

Fragility

- Systems that are robust face fragility and performance setback as an inherent trade-off
- Unexpected perturbations can lead to catastrophic failure

Sophisticated, Complex Behavior

- Often exhibit behavior that is greater than the sum of the parts
### Example of DoD Unique Network Challenges

<table>
<thead>
<tr>
<th>Commercial</th>
<th>Tactical</th>
<th>Military</th>
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</thead>
<tbody>
<tr>
<td>- Mobile Subscriber, Fixed Infrastructure</td>
<td>- High Bandwidth</td>
<td>- Mobile Subscriber - Mobile Infrastructure</td>
</tr>
<tr>
<td>- Pre-configured Networks</td>
<td>- Small Bandwidth</td>
<td>- Ad Hoc, Self-Organizing Networks</td>
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<tr>
<td>- Tall, Fixed Antenna Towers</td>
<td>- Primarily Robust Static Infrastructure</td>
<td>- Small, Easily Erectable Masts; Low Profile OTM Antennas</td>
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<tr>
<td>- Fiber optic Internodal Connections</td>
<td>- Radio-Based Highly Mobile Comms</td>
<td>- Mobile, Wireless, Internodal Connections</td>
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<tr>
<td>- Greater Frequency Spectrum Availability</td>
<td>- Highly Skilled Large Teams</td>
<td>- Restricted Frequency Assignments; Geographically Impacted</td>
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<tr>
<td>- Fixed Frequency Assignments</td>
<td>- MOS w/Multi-duties</td>
<td>- Protection: None → Top Secret/ SI (Multiple, Simultaneous Levels)</td>
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<tr>
<td>- Protection: None → Privacy (single level)</td>
<td></td>
<td>- Interference Rejection and Antijam are Critical</td>
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<tr>
<td>- Interference Rejection is Somewhat Important</td>
<td></td>
<td>- Low Probability of Detection (LPD) is Critical</td>
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<tr>
<td>- Low probability of Detection (LPD) is not an issue</td>
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**Strategy** = **Adopt**

**Adapt**

**Develop**
- Social and communications networks lie at the core of all military operations
- A fundamental understanding of complex and social networks is primitive
- Required for true, full NCO capability
- Current funding/programs focused on specific applications
- Research is fragmented
In order to implement its investment strategy in network science, technology, and experimentation (NSTE), the Army should organize a center for (NSTEC) with a mission to:

- Develop basic knowledge of networks, including social and cognitive, communication, and information domains
- Attract the best researchers in network science
- Manage activities in network science research, technology development, and experimentation for the Army
- Focus science and technology (S&T) investments to enable network-centric operations and warfare
- Focus applied S&T to enable social networks important to Army operations
- Enable development of network science applications and facilitate their transition to Army and joint operations
Creation/discovery of a scientific field often leads to unanticipated and revolutionary technology advances, as illustrated in these examples.
### DDRE Grand Challenges
- Information Assurance
- Network Sciences
- Counter WMD
- Science of Autonomy
- Information Fusion & Decision Science
- Biosensors and Bio-inspired Systems
- Quantum Information Sciences
- Energy & Power Management
- Counter Directed Energy Weapons
- Immersive Science for Training & Mission Rehearsal
- Human Sciences

### ARL – Strategic Technical Initiatives
- Information Assurance
- Network Science
- Robotics
- Information Fusion
- Bioscience
- Advanced Computing
- Power and Energy
- Neuroscience
- System of Systems Analysis
- Nanoscience

### TRADOC Top-10 Warfighter Outcomes
- Battle Command Network
- Counter IED and Mine
- Unmanned Systems Opns
- Battlespace Awareness
- Human Dimension
- Power and Energy
- Force Protection
- Training
- Force Application
- Logistics

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**New Network Science Divisions created within ARL-CISD and ARL-ARO**
Enhance Army’s network science & technology research program and:

- Create a Sustainable World-Class Network Science Virtual Center awarded through the Net Sci CTA
- Strengthen & Exploit Government-Industry-Academia Partnerships
- Adopt a Multidisciplinary, Full-Spectrum Approach
- Accelerate the Transition & Improve the Relevance of Army-Sponsored Research
- Tightly Couple Efforts at ARL & CERDEC

**Strategy**

- Establish an Army distributed NSTRC of Government, Academia & Industry
- Maintain an internal Network Science program to transition Army-sponsored extramural research
- Establish strategic relationship with the HPC Mobile Network Modeling Institute (MNMI)
- Establish & maintain strategic relationships with the US/UK ITA, ATEC, NRL, AFRL, PEOs, & other DoD agencies

*TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.*
Foundational techniques to model, design, & predict behavior of tactical networks
- Adaptive & secure mobile *ad hoc* networks
- Self-aware, adaptive network control
- Cognitive networking for spectrum agility & efficiency

Understand social & cognitive networks to improve distributed decision-making
- Human-networked information interaction/exchange
- Data exploitation & displays
- Dynamic social-system networks

Integration, evaluation, & analysis of full spectrum decision-making networks
- Lead integration research across: social-cognitive-info-comms-physical
- Modeling & analysis tools & techniques
- Live, virtual, & constructive models

Underpinnings to enable humans & networks to acquire & assimilate information
- Knowledge management: distributed data mining, learned data management
- All-source data to information synthesis
- All-class information to knowledge synthesis
- Secure information exchange, trust & provenance
Network Science Programs

- Basic and applied research spanning Social/cognitive, Information, Communication domains
  - Network Science for Human Decision Making
  - THINK ATO (Tactical Human Integration with Networked Knowledge ATO)
  - STEF (Soft Target Exploitation and Fusion) ATO
  - Node-level multi-modal sensor fusion
  - Network-level distributed/decentralized data & information fusion
  - Network Science for Tactical and wireless emulation for MANETs
- ARO Extramural Programs
  - eSenIF MURI (PSU, Duke, Harvard, OSU)
  - Urban Target Recognition MURI (Berkeley, MIT, Vanderbilt, Memphis)
  - Sensor Fusion Battlefield CoE (Tenn State)
- ARL Technology Alliances and Institutes
  - Advanced Decision Architectures CTA (ending this CY)
  - Communications & Networks CTA (ending this FY)
  - US-UK International Technology Alliance (ITA) on Network & Information Sciences
  - Mobile Network Modeling Institute (High Performance Computing Modernization Program)
- Partnerships with CERDEC: Network Design, TITAN, COBRA
- Multiple related DARPA programs
THE PROGRAM

- Initiated in May 2006
  - Fundamental research in network and information sciences
  - IBM-Led Consortium
  - The Consortium and the US/UK Governments establish an Alliance
  - 5-year program with 5-year option

- Awarded a fundamental research agreement and two transition contracts
  - Total funding for first 5 years = $58M
  - Approximately 50-50% split industry-academia
  - Consortium cost share ~ 12%

- Builds on UK Defence Technology Centres and US ARL Collaborative Technology Alliances

COLLABORATIVE LEADERSHIP

- UK MOD/Dstl and US Army Research Laboratory working together closely to jointly lead program
  - Single coherent fundamental research program
  - Involves US/UK industry, academia, and government

- Promotes collaboration between leading industrial and academic organizations in both countries
  - Collaboratively push the state-of-the-art
  - Critical mass of researchers focused on key challenges
  - Staff rotations to deepen collaborations
  - Develop a deep understanding of how technologies can contribute to future defence capabilities

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
ITA Areas of Investigation

TECHNICAL AREAS

Network Theory (TA1)
Sensor Information Processing and Delivery (TA3)
Distributed Coalition Planning and Decision Making (TA4)
Security Across a System-of-Systems (TA2)

CROSS AREA THEMES and GOAL

- Dynamic Mission Focused Communities of Interest (Cols)
- Enabling Context and Risk Based Decision Making
- End-to-End Coalition Information Flows
- Balancing Resource Efficiency/ Adaptability

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**Simulation**

Use theory to define:
- Objective function
- Behavioral relationships
- Parameters
- Variables

**Emulation**

- PC processors represent nodes
- Laboratory environment
- MANE software to model node movement and radio access
- Actual MANET protocols run on nodes
- Applications run on nodes

**Experimentation**

- Actual hardware in field environment
- Traffic generated from applications
- Realistic scenarios
- HPC used to augment and stimulate environment

**NS Research Facilities**

**HPC-Enabled, Large-Scale, High Fidelity M&S**

**NICE**

TECHNOLOGY DRIVEN. WARFIGHTER-FOCUSED.
Grand Challenge/Vision

- Develop sciences which will enable us to model, design, analyze, predict, & control behaviors of secure tactical communications, sensing, & command & control networks.

- Develop fundamental underpinnings to enable humans & networks of disparate information sources to discover, derive, infer, & optimize data, information & knowledge from the full range of structured & unstructured sources.

- Understand the linkage between the physical & human domains as they relate to human decision making within the Army’s command & control structure.