Army Network Science

NDIA

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Outline

- 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

Network Science

Networks

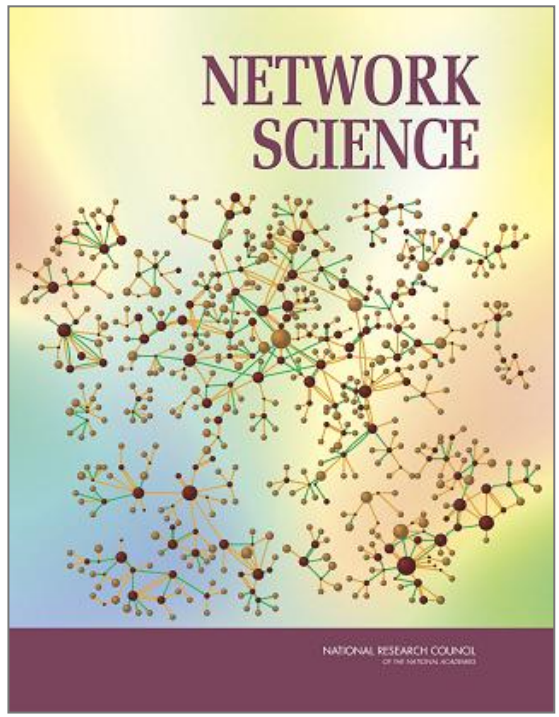
The fundamental components of a network are its structure (nodes and links) and its dynamics, which together specify the network's properties (functions and behaviors).

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



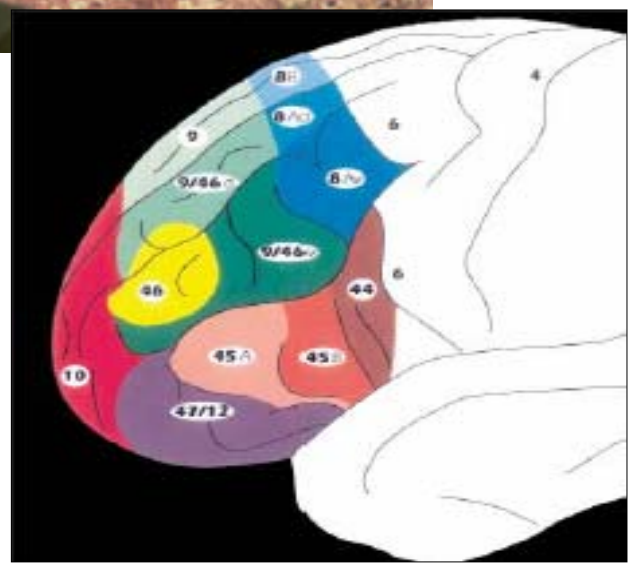
http://fermat.nap.edu/catalog/11516.html

ASA(ALT) commissioned

-- NRC Report on Network Science (2005) --

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

Commercial

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

COMMERCIAL	TACTICAL
	
High Bandwidth	Small Bandwidth
	
Primarily Robust Static Infrastructure	Radio-Based Highly Mobile Comms
	
Highly Skilled Large Teams	MOS w/Multi-duties

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

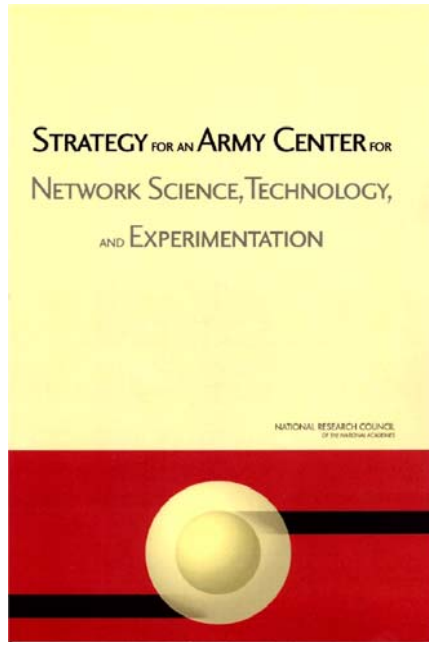
Strategy = ***Adopt*** ***Adapt*** ***Develop***

NRC Study Findings

- **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**

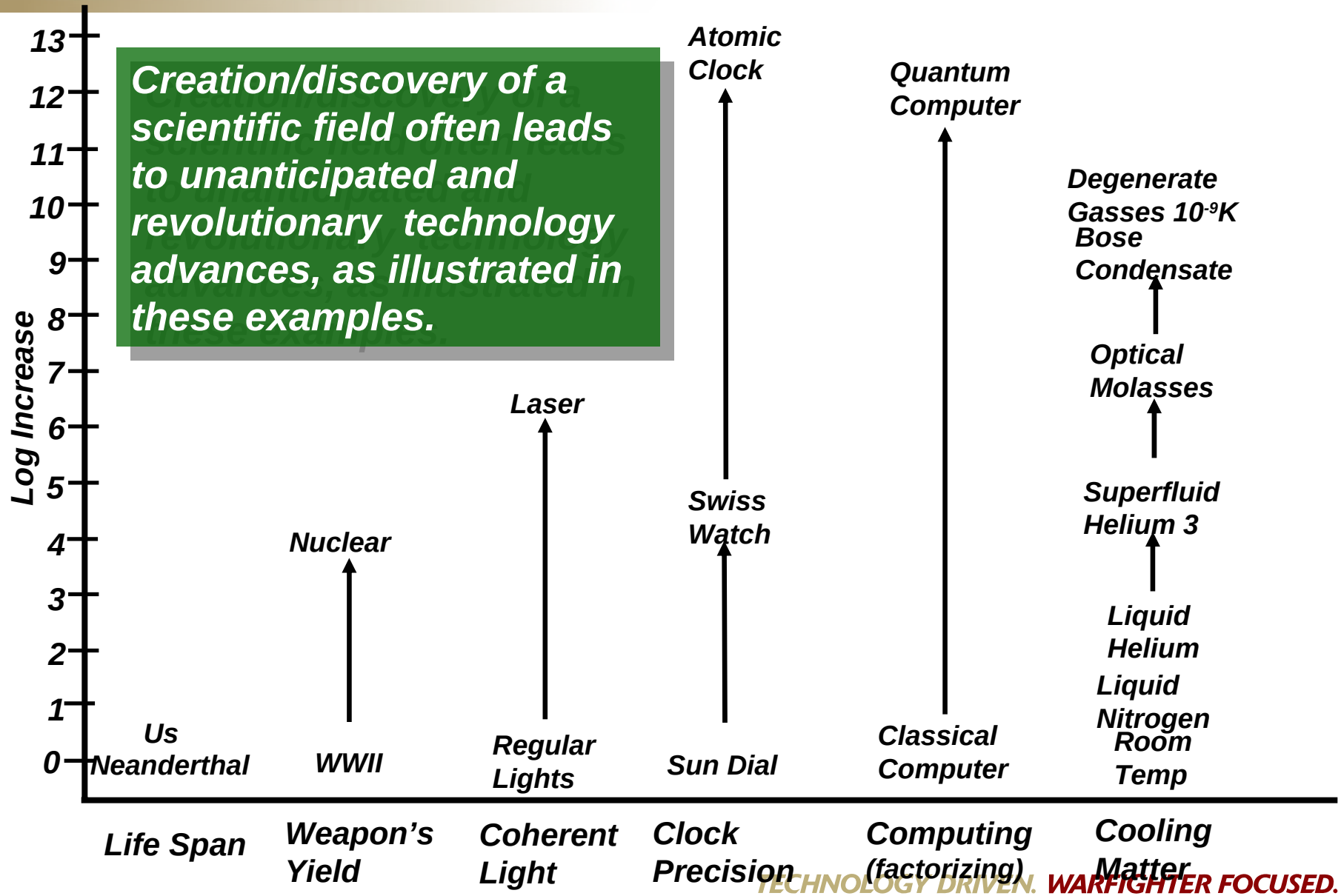
NRC Study
Center Recommendations

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

Ancillary Benefit of Creating NS



Network Science Strategic Guidance

NS receiving high-level strategic and programmatic guidance

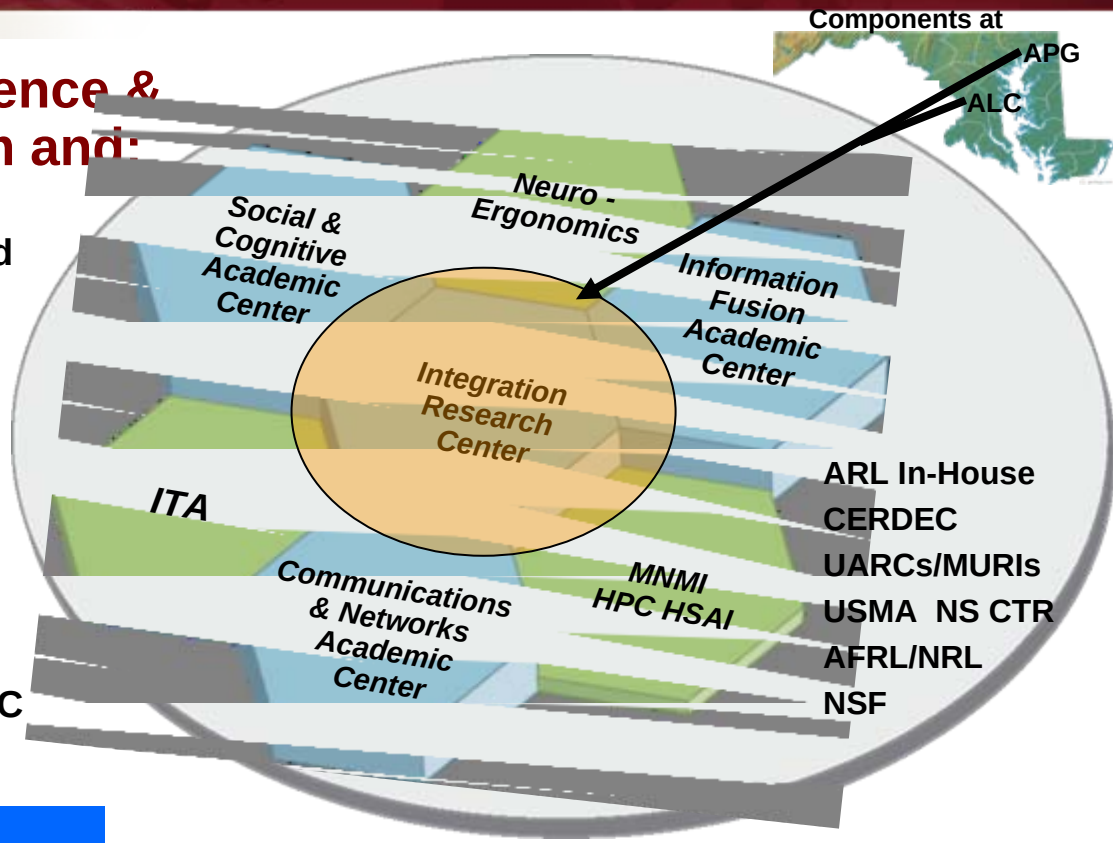
DDRE *Grand Challenges*	ARL – Strategic Technical Initiatives	*TRADOC Top*-10 Warfighter Outcomes
▪ Information Assurance ▪ Network Sciences ▪ Counter WMD ▪ Science of Autonomy ▪ Information Fusion & Decision Science ▪ Biosensors and Bio-inspired Systems ▪ Quantum Information Sciences ▪ Energy & Power Management ▪ Counter Directed Energy Weapons ▪ Immersive Science for Training & Mission Rehearsal ▪ Human Sciences	▪ Information Assurance ▪ Network Science ▪ Robotics ▪ Information Fusion ▪ Bioscience ▪ Advanced Computing ▪ Power and Energy ▪ Neuroscience ▪ System of Systems Analysis ▪ Nanoscience	▪ Battle Command Network ▪ Counter IED and Mine ▪ Unmanned Systems Opns ▪ Battlespace Awareness ▪ Human Dimension ▪ Power and Energy ▪ Force Protection ▪ Training ▪ Force Application ▪ Logistics

New Network Science Divisions created within ARL-CISD and ARL-ARO

Army Network Science Research Plans and Programs

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

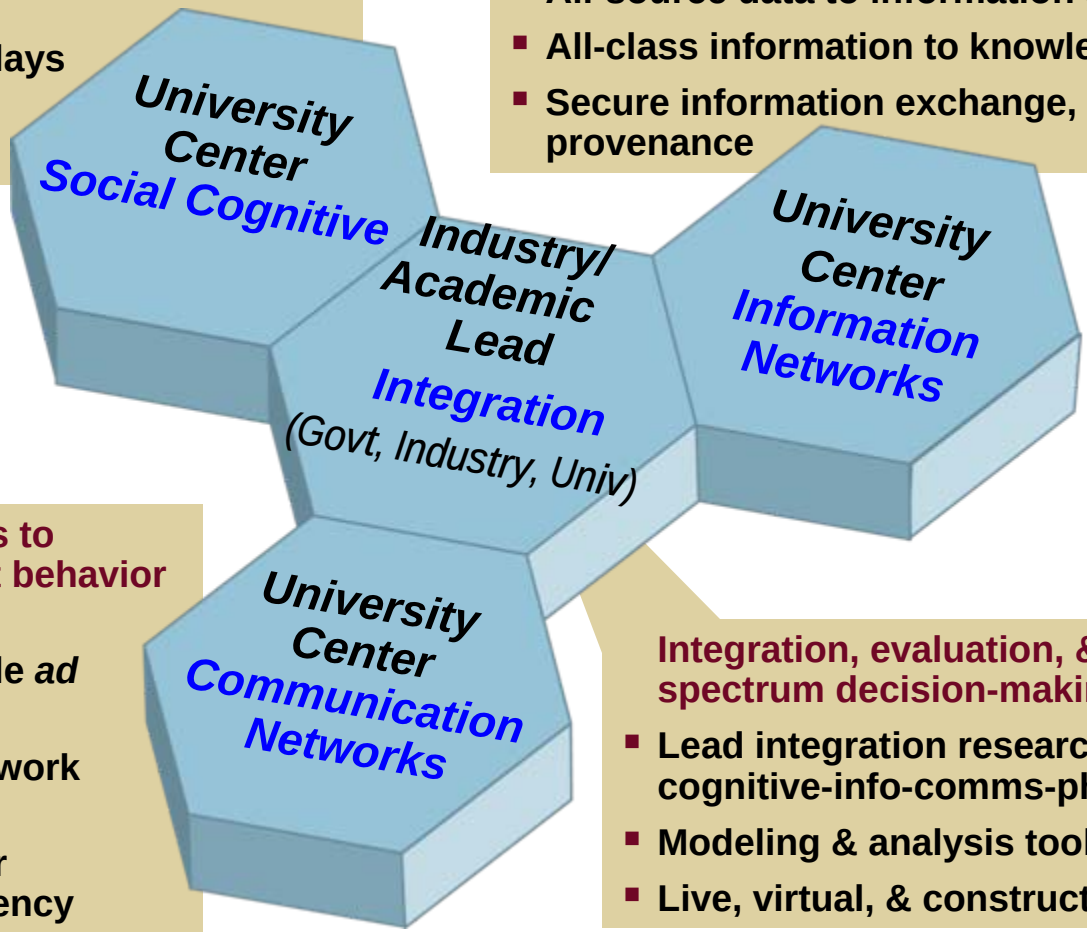
Network Science Collaborative Technology Alliance (NS CTA)

Understand social & cognitive networks to improve distributed decision-making

- Human-networked information interaction/exchange
- Data exploitation & displays
- Dynamic social-system networks

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



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

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

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 ITA Program

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**

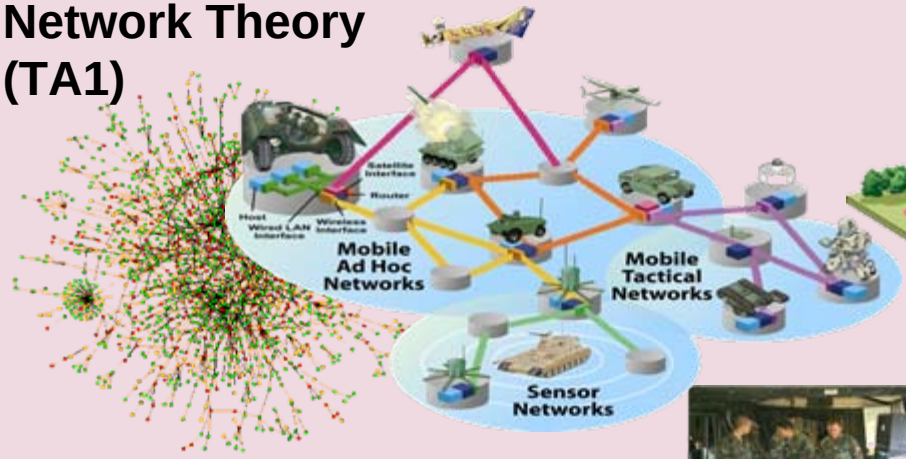
COLLABORATIVE LEADERSHIP

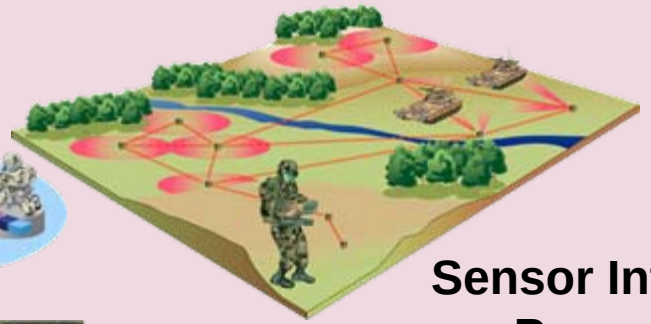
- **UK MOD/Dstl and US Army Research Laboratory working together closely to jointly lead program**
  - Single coherent fundamental research program
  - Involves US/UK industry, academia, and government
- **Promotes collaboration between leading industrial and academic organizations in both countries**
  - 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

ITA Areas of Investigation

TECHNICAL AREAS

Network Theory (TA1)





Sensor Information Processing and Delivery (TA3)

Security Across a System-of-Systems (TA2)

Distributed Coalition Planning and Decision Making (TA4)

CROSS AREA THEMES and GOAL

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

NS Research Facilities

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

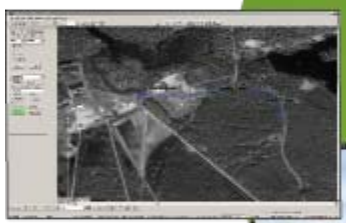
Simulation

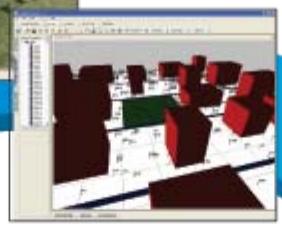
Use theory to define:

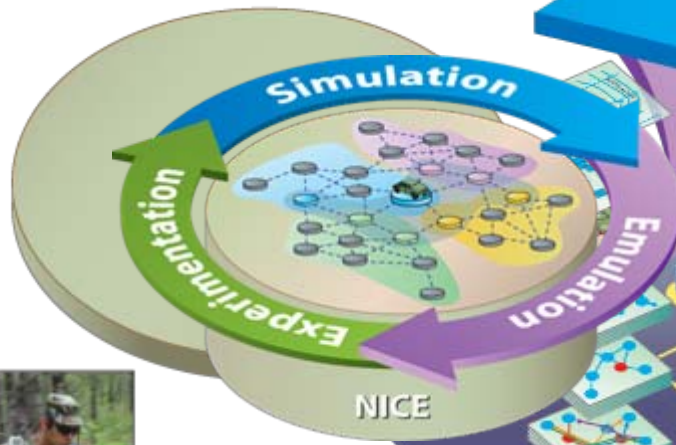
- Objective function
- Behavioral relationships
- Parameters
- Variables

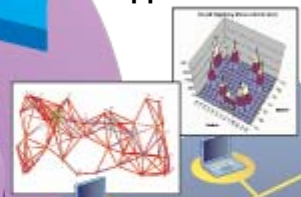
Emulation

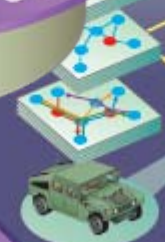
- PC processors represent nodes
- Laboratory environment
- MANE software to model node movement and radio access
- Actual MANET protocols run on nodes
- Applications run on nodes











Mobile Network Modeling Institu

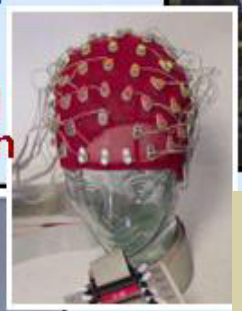
Experimentation

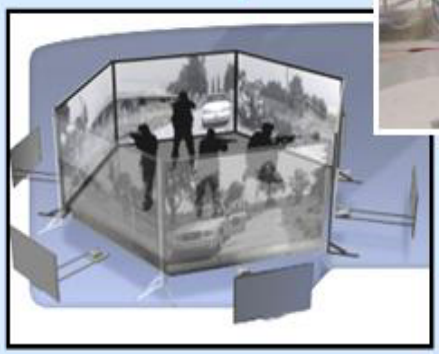
- Actual hardware in field environment
- Traffic generated from applications
- Realistic scenarios
- HPC used to augment and stimulate environment

NS Research Facilities

Simulated Tactical Operations Center (S-TOC)

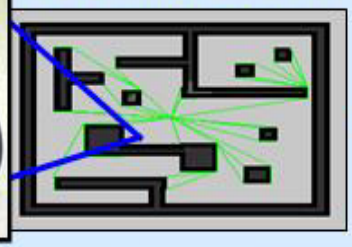
Biosignal acquisition





360° Soldier Readiness Simulator

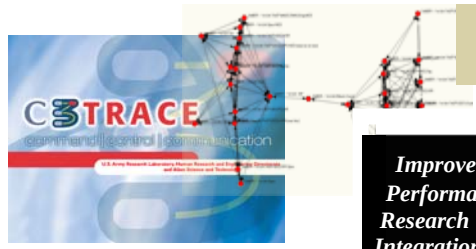
Robot Obstacle Course



Cognitive Assessment, Simulation, & Engineering Laboratory (CASEL)

Bldg 518

Immersive Environment Simulator (IES)



Social Network Analysis

Improved Performance Research Integration Tool IMPRINT

Modeling Tools

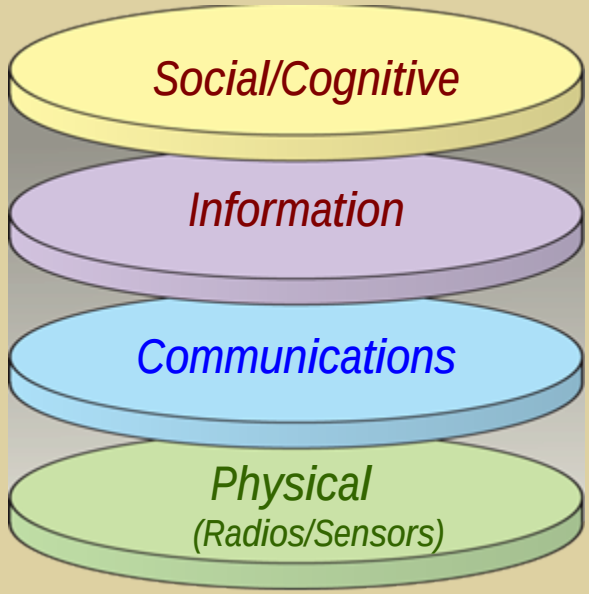
Mobility Portability Course

Shooter Performance Facility

Aberdeen Test Center
Mulberry Point MOUT Site

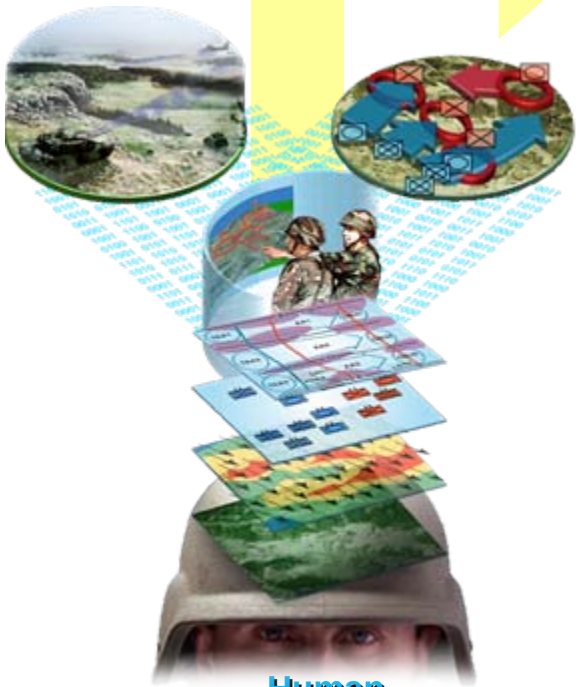
Network Science

Grand Challenge/Vision

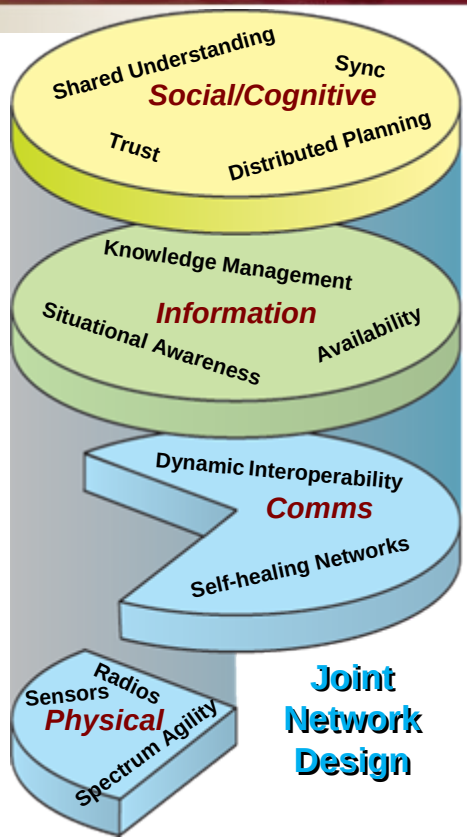


- Develop sciences which will enable us to model, design, analyze, predict, & control behaviors of secure tactical communications, sensing, & command & control networks
- Develop fundamental underpinnings to enable humans & networks of disparate information sources to discover, derive, infer, & optimize 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

Questions/Comments?



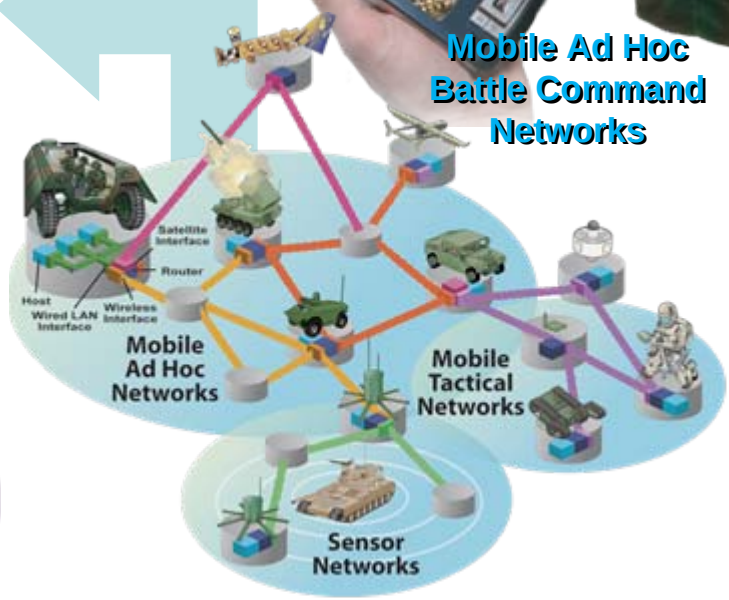
Human Dimensions of Networking



Joint Network Design

HPC-Enabled Large-Scale High Fidelity M&S

- Information Fusion
- Information Assurance



Mobile Ad Hoc Battle Command Networks