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Coalition Command and Control in the Networked Era
Live Virtual Constructive Experiments for C2 Evaluation
Topics: C2 Modeling and Simulation, Coalition Interoperability

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The Evolving Nature of Networked Command and Control (C2)

- C2 relies on commanders receiving and disseminating comprehensive, timely, and accurate intelligence and information, contributing to better overall results.
- Networked C2 is being augmented by increasingly more sophisticated, automated methods to gather, fuse, store, distribute, and utilize battlespace data, thereby increasing overall Situational Awareness (SA).
- Emphasis being placed on equipping lower echelons with integrated network applications to:
  - Enable increased blue and red SA
  - Enhance collaborative planning
  - Invoke assisted and automated target-weapon pairing
  - Improve logistics and maintenance support
  - Enhance embedded training
- Networked C2 requires data to move quickly and reliably through the network.
- **Tactical wireless communications are highly constrained by limitations in the electromagnetic spectrum and the laws of physics.**
- **Communications have not, will not, and cannot keep pace with software and hardware improvements.**
Improving Networked C2 through Systems Engineering

• Tactical network applications must be optimized for network infrastructure, which are:
  – Bandwidth constrained
  – Dynamic
  – Sometimes unreliable

• Emphasis placed on engineering the network:
  – Tailoring network configuration
  – Conducting early capabilities evaluations
  – Measuring network performance in varying operational scenarios

• Network optimization, through effective engineering, is crucial to achieving ultimate operational success:
  – Information superiority
  – Lighter, more nimble force (vs. heavy armor)
  – Enhanced force effectiveness (in conjunction with weaponry) vs. weaponry/brute force alone
  – Less direct contact between friendly and opposing forces
  – Less risk of casualty
Live-Virtual-Constructive (LVC) Experimentation

• Develop and refine an accurate, repeatable, and reproducible Systems Engineering methodology to support network characterization and optimization (vs. evolving operational and technical requirements)

• Implement a Live-Virtual-Constructive (LVC) environment to model C4ISR (including C2) network applications, conduct experimentation, and collect and analyze experimental data

• LVC environment is a Systems Engineering tool for analyzing the performance of network applications and eventual force effectiveness of the future force:
  – Live systems record external stimuli (sensors) and exchange messages (radios):
    • Prototypes
    • Emulations
    • Surrogates
  – Messages transported by constructive simulation network
  – Virtual environment implements Warfighter-in-the-loop C2 functions/tasks

• Greatly facilitates Systems Engineering activities (in support of Risk Mitigation) within a complex System of Systems (SoS) architecture
C4ISR Systems Engineering and Experimentation Laboratory (SE2L)

- Being instantiated in phases to support the development of the Future Combat Systems (FCS)
- Provides an architecture, development environment, and experimental test bed to examine and prove out FCS concepts and refine requirements
- Drives design and implementation of FCS hardware and software through analysis, M&S, and experimentation
- Considers C4ISR systems and subsystems (FCS Family of Systems)
- Considers external, complementary programs interoperating with FCS (FCS SoS)
- Architecture components identified based on:
  - Strong pedigree, uniqueness, substantial historical usage (V&V)
  - Trade studies
  - Benchmarking individual models (normal and stressed operations)
  - Analytical extrapolations (identify model limitations)
- Facilitated by collaboration with C4ISR partners throughout US Army and DoD
Optimizing Modeling and Simulation within LVC Environment

- Trading fidelity, complexity, and maturity of Modeling and Simulation (M&S) tools is necessary to address a wide range of analytical issues within LVC experimentation:
  - Propose initial component concepts
  - Develop candidate architecture products to illustrate component utility
  - Develop requirements for initial concepts and architectures
  - Model preliminary component designs and evaluate designs vs. requirements
  - Assemble M&S representations of various components within LVC architecture
  - Introduce live elements (prototypes or surrogates) if desired
- Iterative process, with feedback used to refine requirements, concepts, designs, and M&S representations
- Ensures mature M&S being used to properly influence C4ISR/C2 requirements/functions:
  - Information collection, fusion, and analysis to make informed decisions
  - Information management to coordinate decisions
  - Timely information dissemination to act upon decisions
C4ISR SE2L Structure

- Divided into two distinct environments:
  - High Fidelity Modeling
  - LVC
- High Fidelity Modeling – very detailed, first principles-based applications supporting component-level analyses:
  - Radiation/wavefront propagation models
  - Sensor models
  - Discrete Events Simulation (DES) tools
- LVC – used to evaluate interactions among systems, plus SoS performance, in real-time:
  - Abstracted software (propagation, sensor, communications) models (based on High Fidelity models)
  - Computer Generated Forces (CGFs)
  - Warfighter-in-the-Loop (WITL) elements:
    - Vehicle cockpit simulators
    - Reconfigurable Desktop Simulators (RDSs)
  - Data Collection, Reduction, and Analysis (DCRA) tools
  - Gateways and Protocol Translators (to live elements, other environments)
  - Evolving Battle Command functionality
High Fidelity Modeling

• C4ISR SE2L uses radiation propagation models which are recognized standards throughout the US Government, industry, and/or academia:
  – MODTRAN:
    • Calculates wide-band atmospheric transmission at a moderate spectral resolution
    • Applicable to EO/IR and visible-band sensors
  – FASCODE:
    • Calculates deterministic transmission, using individual absorption line data, at a single spectral line
    • Applicable to laser propagation (e.g. rangefinders, designators)
    • Supplemented by stochastic propagation applications (to include atmospheric turbulence)
  – TIREM:
    • Calculates RF/millimeter wave path losses due to free-space propagation and terrain effects
    • Applicable to communications waveform models, radar models
High Fidelity Modeling, con’t.

- C4ISR SE2L uses US Army standard wavefront propagation models to predict path losses for acoustic and seismic sensor applications
- Acoustic propagation model includes detailed representations of various influential factors:
  - **Atmospherics:**
    - Time of day
    - Ambient temperature
    - Wind speed/direction
    - Humidity
  - **Terrain:**
    - Ground moisture
    - Topographical features (hills, valleys, peaks)
    - Surface features (sand, grass)
  - Acoustic sources (target signatures, noise sources)
- Seismic propagation model includes detailed representations of soil layers and underlying geological structure
- Propagation models feed sensor models and DES network models/tools with accurate transmission/path loss data (supports sensor performance analyses)
- **Used in mission planning C2 applications for sensor placement**
Sample Propagation Data

Acoustic
- Propagation enhanced by a hill
- Propagation degraded behind hill

RF
- Longley Rice

MWIR
- Rural Extinction, 23 km Visibility, Observer Height 1000 ft AGL,
  1976 US Standard Atmosphere, 3-5 um

LWIR
- Rural Extinction, 23 km Visibility, Observer Height 1000 ft AGL,
  1976 US Standard Atmosphere, 8-12 um

IR
- CO₂ Absorption Band
Notional Network Performance

• Calculated by DES network models/tools (fed by TIREM propagation results):
  • OPNET®
  • Qualnet™
• Reflected in either Message Completion Rate (MCR) or Latency/Delay
• Vary as a function of:
  – Number of simulated network nodes
  – Network loading
  – Message size distribution
  – Message priority
  – Information Assurance mechanisms (for added network security)
• The C4ISR SE2L uses DES network modeling tools which have been provided/approved by Army C4ISR partners

"OPNET“ is a registered trademark of OPNET Technologies, Inc., Bethesda, Maryland, USA
"QualNet“ is a trademark of Scalable Network Technologies, Inc., Los Angeles, California, USA
**Notional IR Sensor/Warfighter Visionics Performance**

- Calculated using visionics models (fed by MODTRAN IR propagation results)
- Vary as a function of:
  - Sensor type
  - Target type
  - Target velocity
  - Acquisition function
- C4ISR SE2L uses representations which have been distributed throughout the FCS program (ensures common M&S methodology)
**LVC Environment – Computer Generated Forces**

- Simulate blue and red entities, entity missions and routes, and terrain
  - Scripted in advance (completely autonomous C2)
  - Scripted with the aid of artificial intelligence (semi-autonomous C2)
  - Assisted by trained scenario developers providing C2 to entities
- Provide Loss Exchange Ratios, lethality data, weaponry hit/miss statistics
- Record and play back exercise results for analysis
- Multiple CGFs can be used to provide necessary levels of force abstraction (Brigade/Battalion level, down to individual vehicles/soldiers)
- The C4ISR SE2L recently simulated a full Brigade Combat Team for a communications capabilities analysis (thousands of nodes)
  - CGF, in conjunction with real-time abstractions of DES network models
  - Network message loading (data/C2 messages, plus sensor imagery) was modeled using the standard traffic database used throughout the FCS program
WITL Simulators

Cockpit Simulators

- Realistic, immersive networked environment
- Instrumentation controls and displays
- Optional motion

- Ideal for:
  - Warfighter training
  - Refinement of tactics, techniques, procedures
  - Refinement of CGF behavior
- Constrained by resource availability

MIRAGE-RDS™ Reconfigurable Desktop Simulators

- Inexpensive, moderate-fidelity alternative to cockpit simulators
- Includes display and functional control within a fixed-base (non-immersive) environment
- Can simulate a wide variety of platforms within a single form factor
**DCRA Tools**

- Displays internode link quality in real time
- Based on LVC network communications models (with TIREM propagation)
- Color-coded based on quality (e.g. green = sufficient, yellow = marginal, red = poor)

**VISUALYZER™ (ISR)**

- Displays ISR sensor targeting performance in real time
- Based on visionics models (with MODTRAN propagation)
- Color-coded based on quality (e.g. green = sufficient, yellow = marginal, red = poor)

**VISUALYZER™ (C4)**

- Bird’s eye view of entire battlespace

**Battlemaster Views**

**ANALYSIM™**

- Collect, analyze, display, and play-back experiment data in real time
Gateways and Protocol Translators

• Implemented to translate among different simulation protocols, as well as between simulation protocols and tactical message formats
• Supporting short- and long-haul network connections between C4ISR SE2L and Live experimentation events (field and laboratory),
  – Currently implemented within Continental United States
  – Events include Joint and Multinational/coalition partners
  – Two field experiments (with laboratory M&S support) addressing Joint and/or Multinational interoperability have been successfully completed
• Future activities will involve extensive collaboration with (and reachback to) multiple coalition partners – demonstrating a greater degree of interoperability/C2 beyond American forces
Sample Battle Command System Display

- Modified in the C4ISR SE2L to display simulated sensor imagery
- Allows warfighter-in-the-loop to:
  - Review sensor output
  - Perform visionics targeting functions (up to and including possible identification)
  - Respond with spot report based on success of targeting function (up to Brigade Headquarters)
- BC capability to be augmented with automated sensor fusion to deconflict and track targets, thereby reducing network traffic
Conclusions

• C4ISR SE2L provides the FCS program with a sound capability, scalable architecture, and LVC environment for supporting Systems Engineering and Risk Mitigation activities within all facets of C4ISR:
  – ISR sensor data collection
  – Communication of ISR sensor data to C2 applications
  – C2 processing and analyzing ISR sensor data
    • Evolving Battle Command
    • Sensor data fusion
  – Timely dissemination and display of C2 data throughout BCT
    • Robust communications networks
    • Warfighter-Machine Interfaces

• C4ISR SE2L will continue to evolve and be exercised as a key component of experimentation involving FCS, Army, Joint, and Multinational/coalition forces

• Information and results will continue to be fed back to decision makers at each level of C4ISR/C2 leadership

• **C4ISR SE2L is postured towards the enhancement of collaborative C2 among the networked, interoperable SoS across many echelons of global warfare for the future force**