Concept Development and Experimentation Course

Concept Development and Experimentation

January 29, 2007

Richard E. Hayes, Ph.D.
President, Evidence Based Research, Inc.
Chief Scientist, Command and Control Research Program (CCRP)

1595 Spring Hill Road, Suite 250
Vienna, VA 22182
703-893-6800, ext. 372
Email: rehayes@ebrinc.com
EBR, Inc. website: www.ebrinc.com
CCRP website: www.dodccrp.org

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Agenda

• Why perform concept development?
• Where do ideas originate?
• Concept development and experimentation
• What is an experiment? Why experiment?
• Challenges for effective experimentation
• Illustrative conceptual models
• Experimentation is not a panacea
• Campaigns of experimentation
• Illustrative experimentation
• Conclusions
Why Perform Concept Development?

• Fundamental changes in the threats to national security
  – From fixed to variable threats
  – From episodic to continuous conflicts

• Fundamental changes in the missions
  – From warfighting to national security
  – Increasing need for international peace operations
  – Requirement for agile capabilities
Why Perform Concept Development? (2)

• Enormous changes in information technologies
  – Capacity to share information
  – Capacity for collaboration

• Massive expansion of relevant partners
  – Not only multinational, but also interagency
  – Not only governmental, but international organizations (IO), non-governmental organizations (NGO), private industry, and local authorities

• From secure within our borders to global linkages
  – NATO out-of-area missions
  – Economic, social, and political arenas
### Threat vs. Military Role

<table>
<thead>
<tr>
<th>Adversary</th>
<th>Military Force</th>
<th>Policing &amp; Monitoring</th>
<th>Supporting Civilian Missions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nation States</strong></td>
<td>Iraq</td>
<td>Bosnia</td>
<td>State Sponsored Counterfeiting and Smuggling</td>
</tr>
<tr>
<td><strong>Sub-National Actors</strong></td>
<td>Kosovo</td>
<td>Somalia</td>
<td>Rwanda</td>
</tr>
<tr>
<td><strong>Organizations</strong></td>
<td>Afghanistan</td>
<td>WMD Technology Transfers</td>
<td>Homeland Security</td>
</tr>
<tr>
<td><strong>Individuals &amp; Networks</strong></td>
<td>Maritime Interception of Immigrants</td>
<td>Drug Interdiction</td>
<td>Illegal Monetary Transfers</td>
</tr>
<tr>
<td><strong>Systemic Challenges</strong></td>
<td>Quarantine to Control Ebola Outbreak</td>
<td>Illegal Fishing/ Pollution Control</td>
<td>Earthquake, Tsunami and Hurricane Responses</td>
</tr>
</tbody>
</table>
The Tenets of Network Centric Warfare

1. A robustly networked force improves information sharing

2. Information sharing and collaboration enhance the quality of information and shared situational awareness

3. Shared situational awareness enables self-synchronization

4. These, in turn, dramatically increase effectiveness and efficiency
Network Centric Operations
Maturity Model

Command and Control

Developing Situational Awareness

Shared Awareness
Information Sharing
Organic Sources

Traditional  Collaboration  Self-Synchronization

0  1  2  3  4

Concept Development: Where Do Ideas Come From?

- The Force and its partners
  - Field Commands
  - Elements of the force
  - Interagency groups
- Lessons learned from operations and exercises
- Deliberate concept development activities
- Research and development communities
- Improved theory and policy
- Technology developers
- By analogy from other fields

New Concepts May Come From Anywhere!
Concept Development and Experimentation: From Theory to Practice

What is an Experiment?

• From the Latin, *experiri*, which means “to try”
  – Knowledge founded upon observation or experience – empirical
  – Requires establishing some level of control
  – Requires manipulation of one or more factors
  – Seeks to identify cause and effect

• Three Types of experiments
  – *Discovery* experiments: to determine the impact of something previously untried (explore the unknown)
  – *Hypothesis testing*: to explore alternative cause and effect relationships (refine knowledge)
  – *Demonstration*: to show established relationships (educate)

• Experiments may involve: Humans only, machines only, humans and machines interacting
Why Experiment?

- Stakes are very high: national interests, lives and treasure
- National security institutions are, therefore, correctly conservative – slow to change
- Experimentation provides a means to:
  - Mitigate risk
  - Identify innovations that are useful and matter
  - Learn conditions under which innovations work
  - Provide empirical evidence to inform policy and budgetary dialogues
Challenges for Effective Experimentation

• Identify the correct research question and mission capability package
  – Relevant to improved mission accomplishment
  – Focused enough for meaningful progress

• Prepare for success
  – Involve stakeholders
  – Build a multidisciplinary team
  – Include domain expertise, experimentation design expertise, and technical support
  – Plan for peer review throughout the process
Challenges for Effective Experimentation (2)

- Conduct rich literature search on prior work
- Develop a conceptual model: an executable one, if possible
  - Objective functions (dependent variables)
  - Controllable independent variables
  - Uncontrollable independent variables
  - Relevant relationships
Challenges for Effective Experimentation (3)

• Create meaningful measures of merit
  – Measures of performance (MOP)
  – Measures of force effectiveness (MOE)
  – Measures of policy effectiveness (MOPE)

• Design a robust experiment
  – Sample the important space
  – Find an adequate facility and technical support
  – Locate appropriate subjects
  – Develop robust data collection and data analysis plans – at the same time
Challenges for Effective Experimentation (4)

- Conduct an end-to-end rehearsal
- Execute the experiment as you designed it
- Conduct effective analyses: immediate and in-depth
- Revise the conceptual model
- Disseminate reports broadly
- Archive and make available data and experimentation artifacts
- Create a community of interest that cuts across operators, researchers and decision makers
Steps in an Individual Experiment

Illustrative Conceptual Model
Self-Synchronization

- Common Perceptual Filters
- High Quality Information
- High Quality Situation Awareness
- Information Availability
- Collaborative C2 Processes
- High Quality Shared Situation Awareness
- Congruent Command Intent
- Effective Self-Synchronization
- Empowering Leadership
- Competence
- Shared Knowledge & Experience
  - Military Education
  - Training
  - Exercises
  - Operations
- Trust
  - Informational
  - Organizational
Experimenteration is Not a Panacea

- Experimentation is one tool in the tool kit
- Experimentation is appropriate when:
  - A valid, reliable, and credible environment is available
  - The important part of the problem space can be identified
  - The number of variables to be studied is modest
  - The time and resources are available for quality experimentation
- Experimentation is properly employed as one part of a larger effort
- Campaigns of experimentation, including supporting events (seminars, war games, modeling activities, peer review sessions, etc.) are superior to isolated experiments
Why Conduct Campaigns of Experimentation?

- Individual experiments lack the breadth and depth necessary to support intelligent innovation
  - To achieve adequate control for validity, individual experiments focus on manipulating a few variables while seeking to control many others
  - The set of controls and assumptions used in a single experiment must be explored in others in order to ensure that the knowledge gain is valid
  - Replication of results is essential in order to avoid undetected problems arising from errors in design, measurement, or biases
Why Conduct Campaigns of Experimentation? (2)

- Campaigns of experimentation benefit the community by:
  - Focusing attention on specific innovations (MCPs) and exploring their potential or impacts
  - Accelerating progress toward specific objectives (e.g., polio vaccine)
  - Reducing risks associated with innovations, and
  - Improving the efficiencies of some practice or process
- Campaigns of experimentation balance the needs for variety and replication

Campaigns of Experimentation are intended to improve actionable knowledge
The Experimentation Campaign Space

Maturity of Knowledge Contribution
- Discovery
- Preliminary Hypothesis
- Refined Hypothesis
- Demonstration

Complexity (Multi-dimensional)
- Simple
- Complex

Campaign Vector
- Fidelity of Experimentation Settings
- Modeling and Simulation
- Low Fidelity
- High Fidelity
- Laboratory Settings
- Exercises

Conceptual Model for Network-Enabled Meta-Campaign of Experiments

C2 Approach
- Decision Rights
- Interactions
- Information Distribution

Cognitive Information
- Shared Information
  - Quality of Information
- Quality of Awareness
  - Quality of Understanding
- Quality of Shared Awareness
  - Quality of Understanding
- Plans/Decisions
  - Quality of Synchronization

Social

Actions
- Quality of Synchronization

Effects Space
- Specific Effects
- Rate of Change

Mission Space
- Complexity
- Uncertainty
- Risk
- Characteristics of Mission
- Strength of Information Position

Environment
- Complexity
- Uncertainty
- Risk
- Characteristics of Entities
- Situational Familiarity
- Number and Variety of Entities

Quality of C2
- Requisite Agility
  - Effectiveness
  - Efficiency

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Concept Development and Experimentation Course – Allied Command Transformation
29 Jan – 2 Feb 07
Conceptual Model for Network-Enabled Meta-Campaign of Experiments

C2 Approach
- Decision Rights
- Interactions
- Information Distribution

Sensemaking
- Shared Information
  - Quality of Information
- Quality of Awareness
  - Quality of Understanding
- Quality of Shared Awareness
  - Quality of Understanding

Social
- Plans/Decisions
  - Quality of Synchronization

Actions
- Quality of Synchronization

Effects Space
- Specific Effects
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- Complexity of Mission
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ELICIT: A New CCRP Campaign

• Experimental laboratory for investigating collaboration, information-sharing, and trust (ELICIT)
• Information sharing focus
• Controls for:
  – Organizational structure
  – Information distribution mechanism
  – Communication between players
• Variety of experimental subjects
  – Several Boston area universities
  – Naval Postgraduate School
  – UK, Singapore, Canada, and Germany
  – Others under discussion
• Produces a detailed transaction log
  – Assembling as a database
  – Multiple teams developing analytical approaches
Anatomy of a Success: CPOF (1)

- Originated as a Defense Advanced Research Project Agency (DARPA) Project
  - Senior retired military support
  - Improved visualization technologies
  - Greater bandwidth becoming available
- First DARPA experimentation program
  - Broad multidisciplinary team
  - US Army and USMC as potential transition targets
  - Team and knowledge building activities
  - Several limited objective experiments
  - Research phase culminated in a series of war games
  - Many of the initial technologies discarded
- Transition a mixed bag
  - USMC declined
  - US Army accepted
  - Deployed to Iraq with First Cavalry Division
Anatomy of a Success: CPOF (2)

- **Field Experience**
  - Initially division headquarters
  - Expanded over time to brigades and some battalions
  - DARPA technical support for revision in the field
  - Data collected and sent to DARPA repository (reality instrumented)
  - Users debriefed during and after field experience
  - DARPA still processing data

- **Current Status**
  - US Army considering service wide adoption
  - US JFCOM considering adoption in joint arena
  - Returned to experimentation phase
Integrated Battle Command (IBC): On-Going Campaign

- Enabling tool for the whole of government approach: US DARPA and US Joint Forces Command
- Phase 1 (Proof of Concept) Completed
  - Federated models support improved decision making and planning
  - From actions to effects
  - Potential exists to shrink planning teams
  - Change in process and perspectives (unexpected result)
Integrated Battle Command (IBC): On-Going Campaign (2)

- Phase 2: Capability Development
  - Limited Objective Experiment (LOE) 1: Visualization and Human Machine Interfaces
  - LOE 2: From desired effects to potential sets of actions
  - Introducing mini-experiments
  - Incorporating new models
    - Theory of conflict
    - Planning tools
  - Tracking informal organization and process
  - LOE 3 and Capstone: Compare current planning organizations and processes to IBC supported alternatives
Integrated Battle Command (IBC): On-Going Campaign (3)

- **Assessments**
  - JFCOM: Qualitative improvements – SME desirability
  - DARPA: Quantitative improvements (resources, time, options and effects considered)
Synergies of Multi-Pronged Efforts

Understanding Command and Control

C2 state of the practice

possibilities

knowledge

requirements

focus

data

metrics

state of the practice measure

experiments state of the practice

requirements

ideas

possibilities

focus

data

knowledge

state of the practice

Two Persistent, Pernicious Problems

- Focus on Innovation by purchasing objects
  - Not all nations or partners are resource rich
  - Objects, including IT systems, are enablers
  - Many important improvements can be accomplished by changes in policies and processes
    - Information sharing
    - Collaboration

- Lack of broadly accessible Knowledge Base for experimentation
  - Sharing concepts, data, metrics, etc. reduces costs
  - Needed to answer the key questions
    - What experiments have been done?
    - What experiments are underway or planned?
    - Which key concepts and ideas are being ignored?
Broad Guidance for Successful Campaigns of Experimentation

- Assume that the planning and execution of individual experiments follow the known best practices.
- Create the conditions necessary for success:
  - Build a strong, multidisciplinary team, and
  - Create an explicit conceptual model.
- Conduct a sound campaign:
  - Plan for, execute, and pay attention to peer review,
  - Maintain the Conceptual Model over time,
  - Create a database, including “metadata” tags,
  - Capture and document experimentation artifacts (scenarios, measurement tools, surveys, etc.)
- Conduct analyses beyond the individual experiments (model-experiment-model, cross-cutting analyses within the campaign, comparative analyses with studies outside the campaign)

- Create a foundation for the future:
  - Widespread distribution of results, across the relevant Communities of Interest (COI)
  - Making data available to other researchers, and
  - Preserving experimentation artifacts and making them available to others in the relevant COIs
Conclusions (1)

• Weaknesses in current experimentation tend to cluster around failures to:
  – Build the necessary multi-disciplinary team needed
  – Conduct an adequate literature search so the effort is properly focused
  – Select topics that have both short and long term value
  – Define and maintain the conceptual model properly
  – Develop appropriate metrics – valid, reliable, and credible
  – Invest adequately on pre- and post-experiment activities
  – Make the results (data, artifacts, and findings) available across the community
Conclusions (2)

- Campaigns of Experimentation, including supporting events (seminars, war games, modeling activities, peer reviews) and analyses are essential
  - A series of Limited Objective Experiments is wise
  - Capstone events are best used as demonstrations
  - US DARPA is initiating a program of “mini-experiments”
- Experimentation is not an end in itself
- Innovation is not an end in itself
- The goal is Mission Capability Packages that matter!
• **Command Arrangements for Peace Operations** (Alberts & Hayes, 1995)

• **Understanding Information Age Warfare** (Alberts et al, 2001)

• **The Code of Best Practice for Experimentation** (Alberts et al., 2002)

• **NATO Code of Best Practice for C2 Assessment** (SAS026, 2002)

• **Power to the Edge** (Alberts & Hayes, 2003)

• **The Code of Best Practice for Campaigns of Experimentation** (Alberts & Hayes, 2005)

• **Understanding Command and Control** (Alberts & Hayes, 2006)

• **Complexity, Networking, and Effects-Based Approaches to Operations** (Smith, 2006)

• **The Logic of Warfighting Experiments** (Kass, 2006)

• **Guide for Understanding and Implementing Defense Experimentation (GUIDEx)** (TTCP, 2006)

• **Planning: Complex Endeavors** (Alberts & Hayes, 2007)