Code of Best Practice for Joint Experimentation
Agenda

- Overview
- Specifics
- Piggybacking
- Duck Bites
- The Pay Off
- Summary
Background

- AIAA Task Force formed May 1998 to develop a Code of Best Practice (COBP) for Joint Experimentation with focus on Information Superiority
- Activities to date
  - Quarterly meetings focused on experimentation sites and issues
  - ISX 1.1: Assessment of process and lessons learned within EFX 98
  - JEFX 99 (Assessment methodology)
  - JEFX 00 (Concept development)
  - Modeling and Simulation in Joint Experimentation Workshop (December 98)
  - Support for Military Operations Research Society (MORS) Mini-Symposium & Workshop (March 99) on Joint Experimentation
Definitions

- **Experiment** - To determine the efficacy of something previously untried (hypotheses generation), to examine the validity of a hypothesis (hypotheses testing), or to demonstrate a known truth (demonstration). Experiments are always empirical (involve systematic observation and measurement). Experiments involve three phases: Pre-, Conduct and Post-

- **Experimental Campaign** - A series of related activities that explore and mature knowledge about a concept of interest (voyage of discovery).

- **Experimental Venue** - An integrated construct designed to support individual initiatives.
The Experimental Space

Maturity of Knowledge Domain

- Discovery
- Preliminary Hypothesis
- Refined Hypothesis
- Demonstration

Complexity (Multi-dimensional)

- Echelon
- Uncertainty
- Information Flow
- Interaction
- Number of Actors
- Domain Structure
- Stability of Environment
- Functional

Campaign Vector

Tools

- Real World Lessons Learned
- Live Exercises
- M&S (constructive, virtual)
- Wargaming
- Expert Elicitation
- Brainstorming

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Version 10
The Experimental Space (con’t)
Maturity of Knowledge Domain

- **Demonstration Experiments**
  - Predictive models
  - Estimates values of some factors given values of others

- **Preliminary and Refined Hypothesis Experiments**
  - Explanatory models
  - Models cause and effect
  - Explains how different factors interact

- **Discovery Experiments**
  - Conceptual models
  - Identify important factors
  - Enables process classification
Types of Tools

- **“Soft” Operational Research Tools**
  - Brainstorming
  - Expert elicitation
  - Wargaming
- **“Solving” Tools**
  - Linear programming
  - Heuristic searching
- **Modeling and Simulation**
  - Constructive, virtual tools
  - Live events
- **Real World Lessons Learned**
- **Supporting Tools**
  - Data analysis
  - Visualization
  - Data mining
# Dimensions of Complexity

<table>
<thead>
<tr>
<th>Factor</th>
<th>Simple</th>
<th>Complex</th>
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<tbody>
<tr>
<td>Number of Actors</td>
<td>Few (Homogeneous)</td>
<td>Many (Heterogeneous)</td>
</tr>
<tr>
<td>Stability of Environment</td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Echelon</td>
<td>One</td>
<td>Many</td>
</tr>
<tr>
<td>Function</td>
<td>Single</td>
<td>Multiple</td>
</tr>
<tr>
<td>Information Flow</td>
<td>Stovepiped</td>
<td>Networked</td>
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<tr>
<td>Interaction</td>
<td>Non-interactive</td>
<td>Fully Interactive</td>
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<tr>
<td>Domain Structure</td>
<td>Poorly Defined</td>
<td>Well Defined</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Low</td>
<td>High</td>
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The Campaign Plan

- **Purpose:** Explore and mature a concept
- **Goal:** Develop requirements for Mission Capability Packages (MCPs) {e.g. DOTMLP plus other considerations}
- **Concept:** Several linked activities designed to transit the experimental space
  - Some concept explorations will share experimental events
  - Thematic experimental activities may generate concepts for specific exploration
- **Best Practice and Guidelines**
  - Must parse the key concept into meaningful parts
  - Develop structure that insures capabilities for valid generalization
    - Balance of control and live play
    - Baselines and control cases
    - Minimize intrusions
The Creation of a Mission Capability Package

Embryonic MCP

Mission

Ideas

Technology

Discovery Experiments

Force Structure

Command and Control

Doctrine

Technology Requirements

Concept Development

Hypothesis Testing

Analysis

Models

Wargaming

ATDs

Simulations

Concept Refinement

Confirming Experiments

Doctrine Development

Command Reorganization

Education

Training

Systems Development

Concept Implementation

Fielded Mission Capability Package

CO-EVOLUTION

Organization

CONOPS/Doctrine

Command Arrangements

Logistics

C4ISR Systems

Weapons Systems

Training/Education

Personnel

Mission Capability Package

E X P E R I M E N T A T I O N
Campaign Plan Progression

Maturity
- Concept (High Risk)
- Demonstrated Capability (Low Risk)

Concept

Process
- Discovery/Experiment
- Preliminary Hypothesis
- Refined Hypothesis
- Demonstration

Products
- Research & Development Priorities
- JROC Acquisition
- Military Capability Package Requirements

- Developed and Refined Military Capability

- Preliminary Hypothesis
- Refined Hypothesis
- Demonstration

- Research & Development Priorities
- JROC Acquisition
- Military Capability Package Requirements

- Developed and Refined Military Capability
Balanced Experimentation

Pre-Experiment

Experiment

Post-Experiment
Campaign Plan Concept: Linked Experiments

- Pre- and Post-Experimental activities largely depend on analytic tools to include constructive, virtual, and M&S.

- Knowledge gained is often greatest in Post-phase but quality of that knowledge depends heavily on the Pre-Phase preparation and planning.
COBP Milestone Timeline

Pre-Experiment Phase
- Define objectives & concepts, establish experimental task force
- Plan the experiment
- Good Idea Cut-off Date
- Stabilize Exp. Infrastructure
- Initiate training
- Rehearse and pre-test

Experiment Phase
- Conduct the experiment
- Conduct supporting M&S
- Ensure quality control
- Provide interim assessments & hotwashes

Post-Experiment Phase
- Analyze data
- Generate products
- Review products
- Disseminate products

Time in % of Overall Experimental Activity

0 25 50 75 100
Balanced Experimentation
Phases of Activity

• **Pre-Experiment: Determines Potential for Success**
  – Sharpens focus
  – Assesses feasibility
  – Maximizes success in the “Real World”

• **Experiment: Enables Success**
  – Emphasizes credibility
  – Increases visibility
  – Generates data

• **Post-Experiment: Explores Success, Consolidates Gains**
  – Extends data and assesses sensitivity
  – Translates data to information/knowledge
  – Prepares and focuses next experiment
  – Feeds other communities
    (i.e. Acquisition, Doctrine, Training)
The Pre-Experiment Phase (1 of 4)

- Define objective of the experiment
- Develop and refine the concept(s)
- Identify one or more hypotheses to be tested/characterize variables
- Establish context of the hypotheses
  - Formulate scenarios and interesting parts of the scenario space
  - Identify ranges of the variables
- Assess feasibility and expected utility of experiment by estimating:
  - Costs
  - Other resources required (e.g., personnel, facilities)
  - Expected outcomes
  - Risks
- Execute appropriate models to:
  - Establish parameters
  - Explore the scenario space
  - Test assumptions
Create Plan for Experimentation
- Specify null hypotheses
- Develop operational definitions & measures
- Identify training requirements (for participants, data collectors, etc.)
- Define learning objectives
- Develop data collection and data analysis plans
- Specify required control and adaptation during the experiment

Specify the Experimental Structure
- Dependent variables (objective functions)
- Independent variables
  - Experimental focus
  - Context and conditions

Identify infrastructure needs
- Assure adequacy of models, simulations and tools
- Define facility requirements
The Pre-Experiment Phase (3 of 4)

- Develop configuration management plans
- Specify appropriate Measures of Merit
  - Measures of Performance (MOPs)
  - Measures of C2 Effectiveness (MOEs)
  - Measures of Force Effectiveness (MOFEs)
  - Measures of Policy Effectiveness (MOPEs)
- Specify other observables of interest
  - Meaningful scale points
- Refine data collection and data analysis plans
The Pre-Experiment Phase (4 of 4)

• **Create experimental environment**
  – Provide infrastructure
  – Create scenario
  – Install data driver
  – Install models, C3I
  – Integrate and federate models
  – Instrument for data collection
  – VIP interface

• **Select and train participants**
  – Identify contingencies that training should address
  – Tailor selection, training and assessment proficiency for:
    • Friendly and coalition forces (blue)
    • OPFOR (red) and neutral (gray)
    • Control (white team)
    • Data collection and analysis team
    • Quality control team
    • VIP interface

• **Rehearse / Pretest**
The Experiment Phase (1 of 3)

- **Maintain the experimental infrastructure**
- **Run the scenario**
  - Simulate non-live effects
    - Insert sensor inputs, enemy responses, system degradation, operating environment
    - Stimulate, represent, predict, and generate effects
  - Maintain consistent time and granularity
  - Ensure replicability
- **Ensure valid live effects**
- **Conduct supporting modeling or simulation activities**
  - Conduct sanity check/quality control
  - Run additional base-lining with same inputs
  - Play roles
  - Step through control variables
  - Iterate as part of the plan
The Experiment Phase (2 of 3)

• **Execute data collection plan**
  – Collect data in accordance with plan
  – Identify insights

• **Ensure quality control**
  – Sample representative observations
  – Ensure continuous collection

• **Maintain discipline**
  – Maintain the integrity of the experiment
  – Control the scenario
  – Apply exit & restart criteria
  – Manage anomalies
  – Document changes/anomalies
  – Manage experiment
  – Manage configuration
The Experiment Phase (3 of 3)

- **Hold interim assessments**
  - Qualitative
  - Quantitative
  - Evaluate utility of process
  - Identify anomalies
  - Use the “hotwash” to inform the iterative campaign process and enhance quality
  - Visualize data to determine adjustments to experiment
  - Perform intra-experiment adjustment
  - Capture insights

- **Prompt “hotwash”**
  - Identify experimental process insights & lessons recorded
  - Develop major findings based on available data and preliminary observations
  - Identify post-experimental issues
  - Organize for experimental report
The Post-Experiment Phase (1 of 2)

- Execute data analysis plan
- Conduct additional data analyses
  - Sensitivity analysis
  - Extrapolation beyond observed ranges & conditions
  - Explore anomalies/insights
  - Data mining (as appropriate)
- Identify critical issues
- Generate products
  - Use M&S to clarify ambiguous results
  - Develop comprehensive reports and briefings
  - Conduct peer review
  - Promulgate results
The Post-Experiment Phase (2 of 2)

- **Refine/improve M&S**
  - Conceptual
  - Executable

- **Exploit experimental results**
  - Build knowledge base
  - Ensure that “lessons recorded” become “lessons learned”
To maximize probability of success and knowledge gains:

- Establish experimental concept credibility early
- Bound the problem efficiently
- Gain high level visibility and leverage
- Achieve a formal agreement to collaborate
- Ensure sufficient influence on scenario to tailor it
- Obtain early involvement in the planning process (e.g., Stakeholders)
- Capture sufficient resources for training, data collection, and analysis
- Create a robust experimentation environment, including adequate:
  - Number and variety of experimental events
  - Instrumentation
  - Free play (opportunities to fail)
Piggybacking Experiments May Seem Like a Good Idea...
Risks of Piggybacking

- **Loss of Control**
  - Early involvement in planning process necessary to influence scenario building & free play (opportunity to fail)
  - Very detailed backup planning necessary to cope with unplanned events, such as:
    - Adverse weather impacts
    - Experimental infrastructure problems

- **Lack of Visibility**
  - Piggy back event needs leverage on main experiment planning and conduct

- **Lack of Credibility**
  - Hypothesis may not be tested adequately
  - All participants need to collaborate (formally & informally) to ensure
    - Sufficient data collection opportunities
    - Main experiments and piggy backing events do not confound or contradict one another
...But it Does Have Some Risks
A Win-Win Situation

Proper Utilization of an Experimental Campaign Plan Results in a Win-Win Situation

Keith Kirkland:
This is based on Dr. Starr’s final outbrief on behalf of the MORS Synthesis committee.
Duck Bites Can Kill

Planning

Administrative Actions

Preparation

Execution

Data Collection
ISX Lessons Learned (1 of 4)

- **Planning**
  - Limit the number of initiatives
  - Maintain tighter control of the Master Scenario Event List (MSEL)
  - Institute configuration control on hardware, software for all systems in an experiment
  - Select a range with sufficient air, ground, space
  - Schedule ISR assets with sufficient slack time
  - Do not conduct offensive information operations if systems are fragile
ISX Lessons Learned (2 of 4)

• **Preparation**
  – Indoctrinate the players about the objective of the experiment
  – Schedule adequate training on experimental systems, CONOPS
  – Check out communication completely prior to start of live fly activities
  – Establish and maintain improved time synchronization

• **Execution**
  – Synchronize live and simulated events
  – Maintain an equipment status board
  – Establish a white cell to make timely decisions
• Data Collection
  – Provide sufficient data collection tools (e.g., collaborative virtual workstations (CVWs))
  – Install, check-out all data collection equipment at least 3 days prior to live fly
  – Train data collectors/assessors on the experimental process, simulation tools employed
  – Debrief air crews using assessors on the experimental process, simulation tools employed
  – Debrief air crews using assessors (focusing on experiment objectives)
  – Select data collectors/Assessors with the proper backgrounds, familiarity with key systems
  – Develop rapport between the players and data collectors/assessors
• **Administration**
  – Schedule Live Fly Events in times when weather is traditionally good
  – Don’t schedule critical targeting events during lunch hour
  – Provide assistance with classification issues, procedures
  – Enforce discipline in issuing badges
  – Impose greater control on visitors
  – Publish a telephone directory for experimental participants
Impact of the COBP

Current Practice
- **Pre-**
  - Flawed due to:
    - Lack of qualified/experience personnel
    - Lessons recorded are not lessons learned
  - Rushed
  - May required additional resources
- **Experiment**
  - Receives all the attention & the bulk of resources
  - Demonstrations mentality overshadows knowledge collection
  - Inadequate/primitive data capture capability
  - Overemphasis on hotwash - not on sound analysis
- **Post-**
  - Short changed; data not exploited or archived
  - Full promise not realized
  - Some lessons remain unrecorded

COBP
- **Pre-**
  - Appropriate time & resource allocation
  - Correct expertise
- **Experiment**
  - Put “The Show” in proper perspective
  - Emphasizes knowledge gained
- **Post-**
  - Provides more resources
  - Provides more time

Results

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Conclusions

• **Best Practice for Joint Experimentation requires:**
  – An experimental campaign plan that will enable us to explore and mature concepts from idea to Mission Capability Packages (MCPs)
  – Proper emphasis on Pre-Experiment Phase to enhance potential for success
  – Disciplined conduct of actual experiment to enhance knowledge gain and feed subsequent Experimental Events
  – Proper Post-Experiment exploitation to enhance knowledge gained and feed follow-on Pre-Experiment phase

*Proper use of Code of Best Practice can yield greatly enhanced learning.*