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

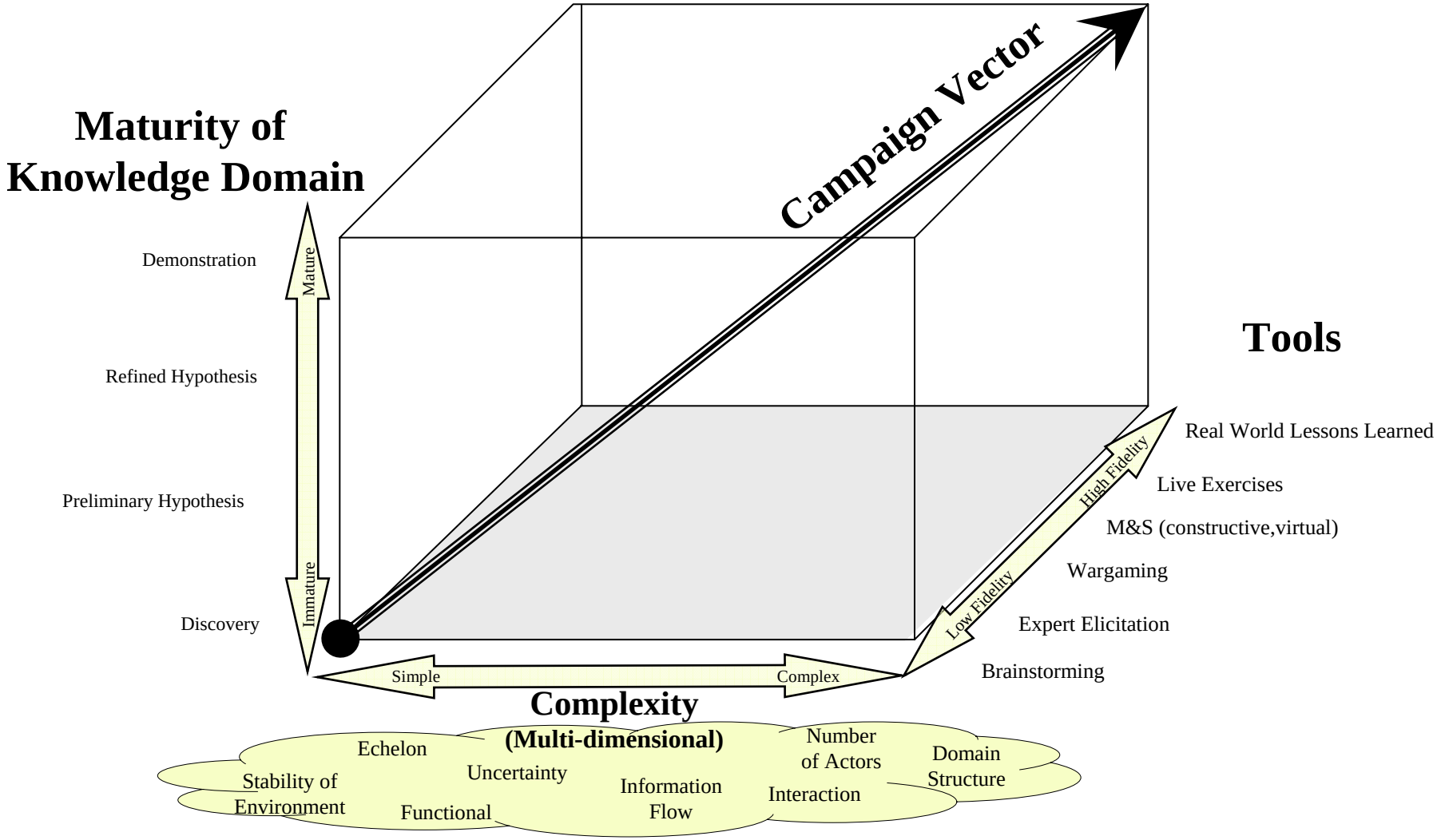
Definitions

- **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-**

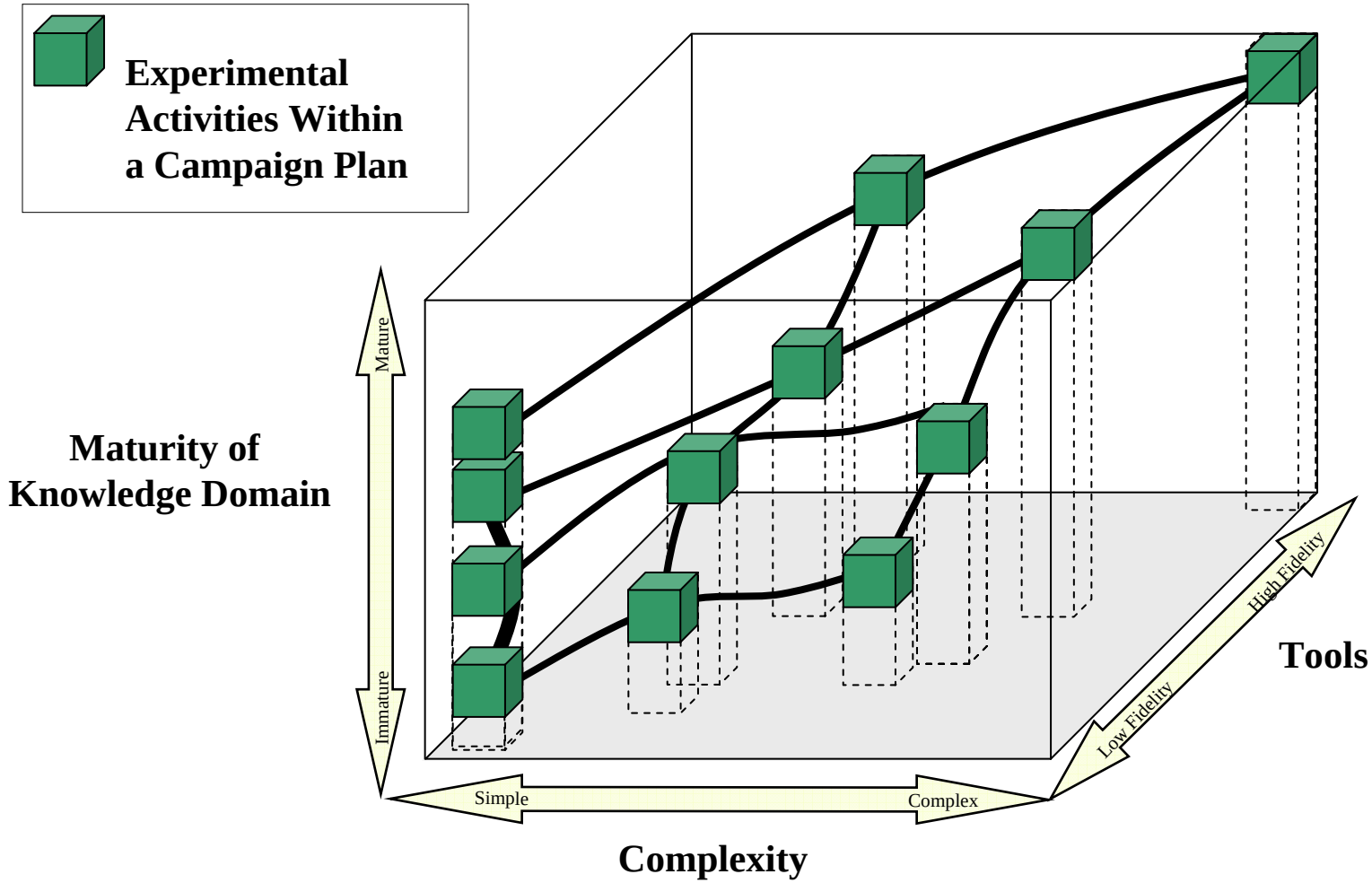
- **Experimental Campaign - A series of related activities that explore and mature knowledge about a concept of interest *(voyage of discovery*).**

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

The Experimental Space

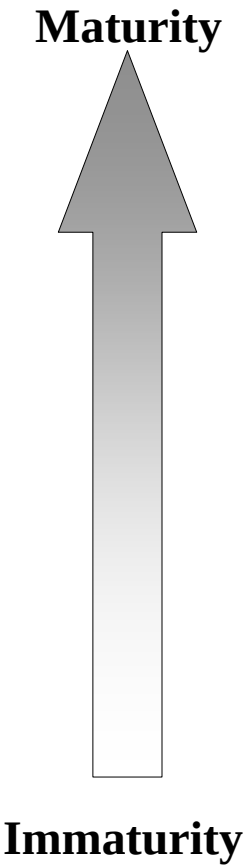


The Experimental Space (con't)



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

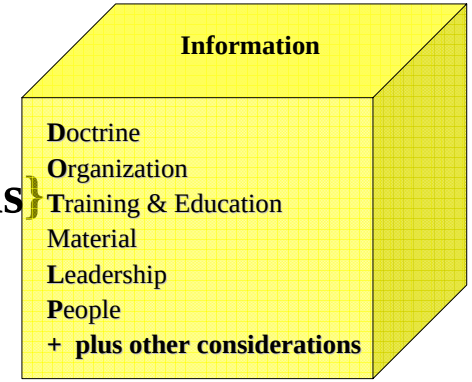
- **"Soft" Operational Research Tools**
  - Brainstorming
  - Expert elicitation
  - Wargaming
- **"Solving" Tools**
  - Linear programming
  - Heuristic searching
- **Modeling and Simulation**
  - Constructive, virtual tools
  - Live events
- **Real World Lessons Learned**
- **Supporting Tools**
  -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

Dimensions of Complexity

Factor	Simple	Complex
• **Number of Actors**	Few (Homogeneous)	Many (Heterogeneous)
• **Stability of Environment**	Static	Dynamic
• **Echelon**	One	Many
• **Function**	Single	Multiple
• **Information Flow**	Stovepiped	Networked
• **Interaction**	Non-interactive	Fully Interactive
• **Domain Structure**	Poorly Defined	Well Defined
• **Uncertainty**	Low	High

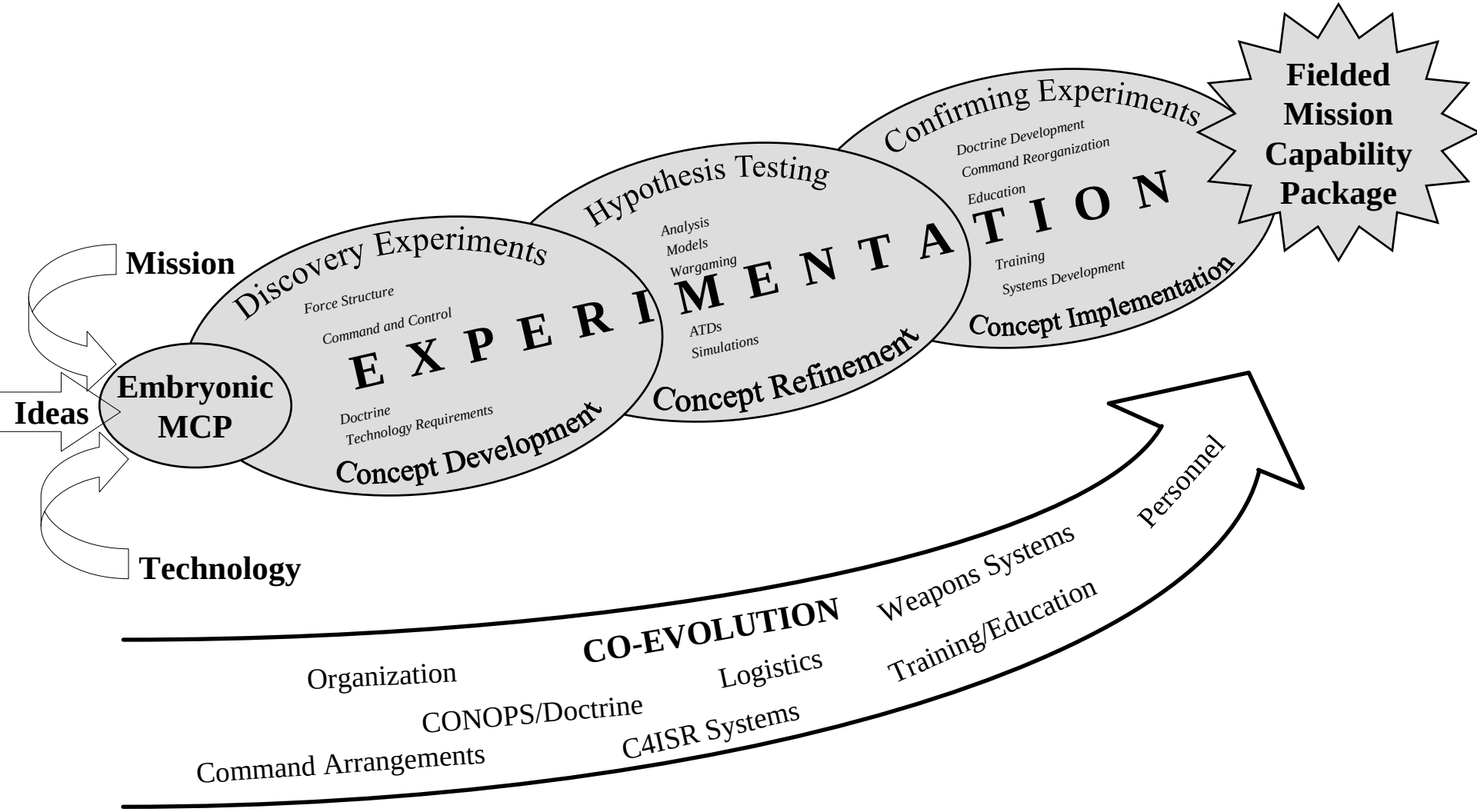
The Campaign Plan

- **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

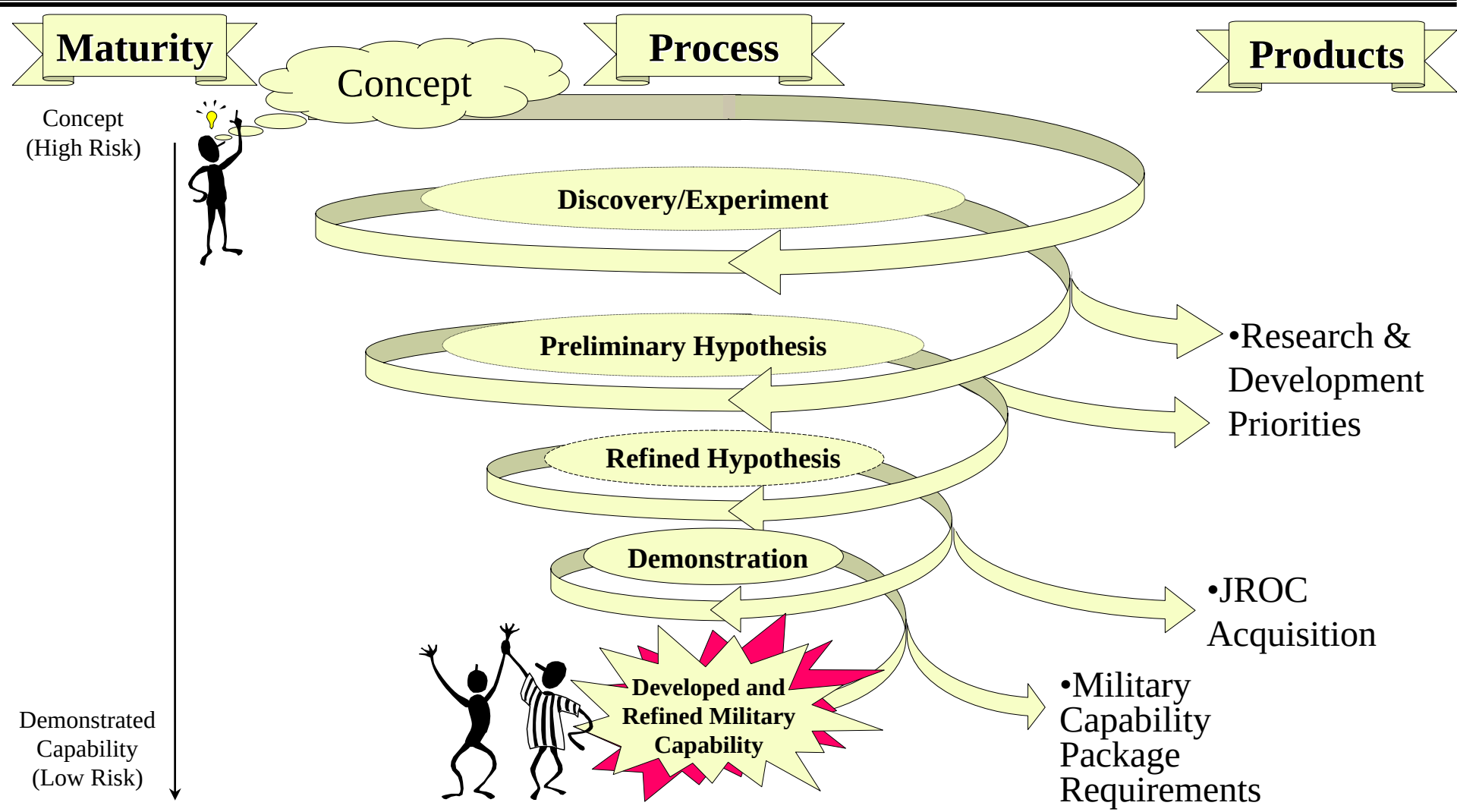


Mission Capability Package

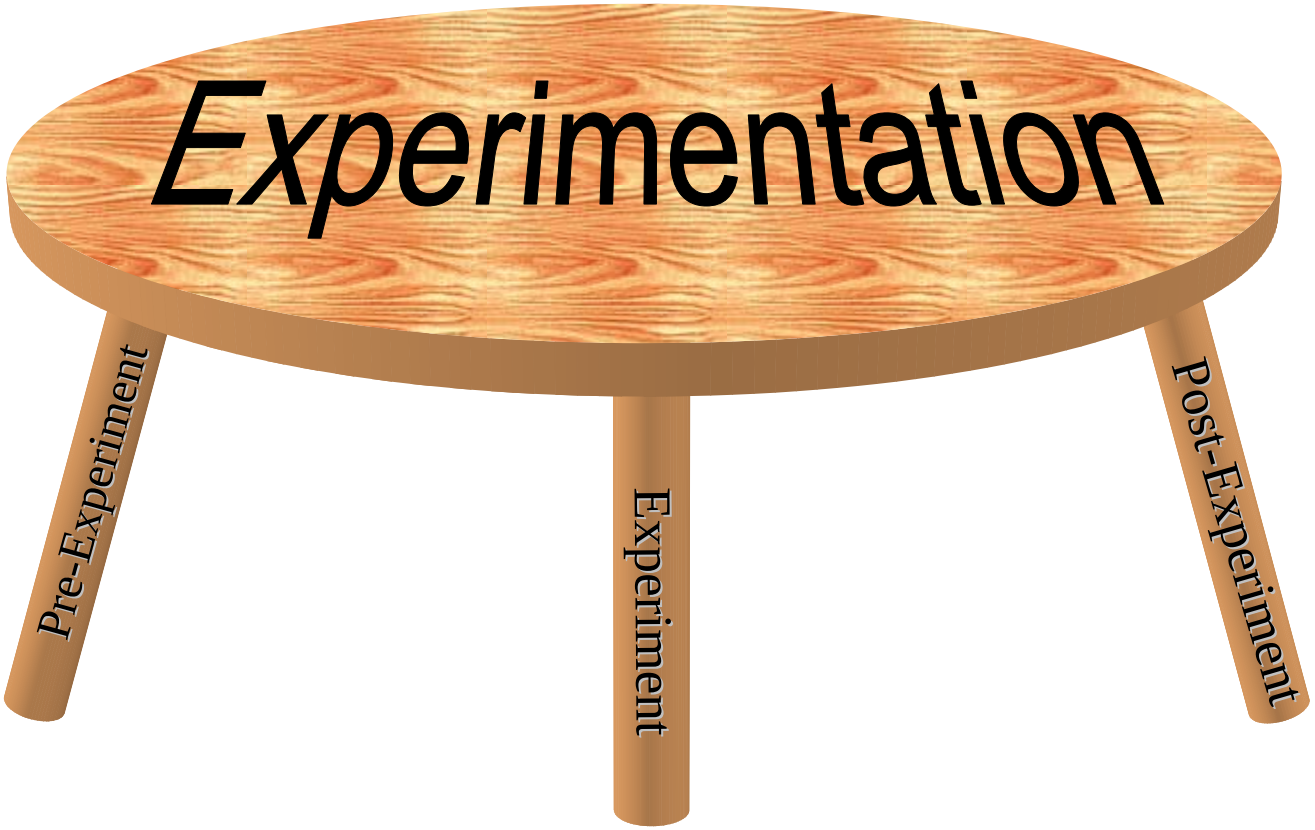
The Creation of a Mission Capability Package



Campaign Plan Progression



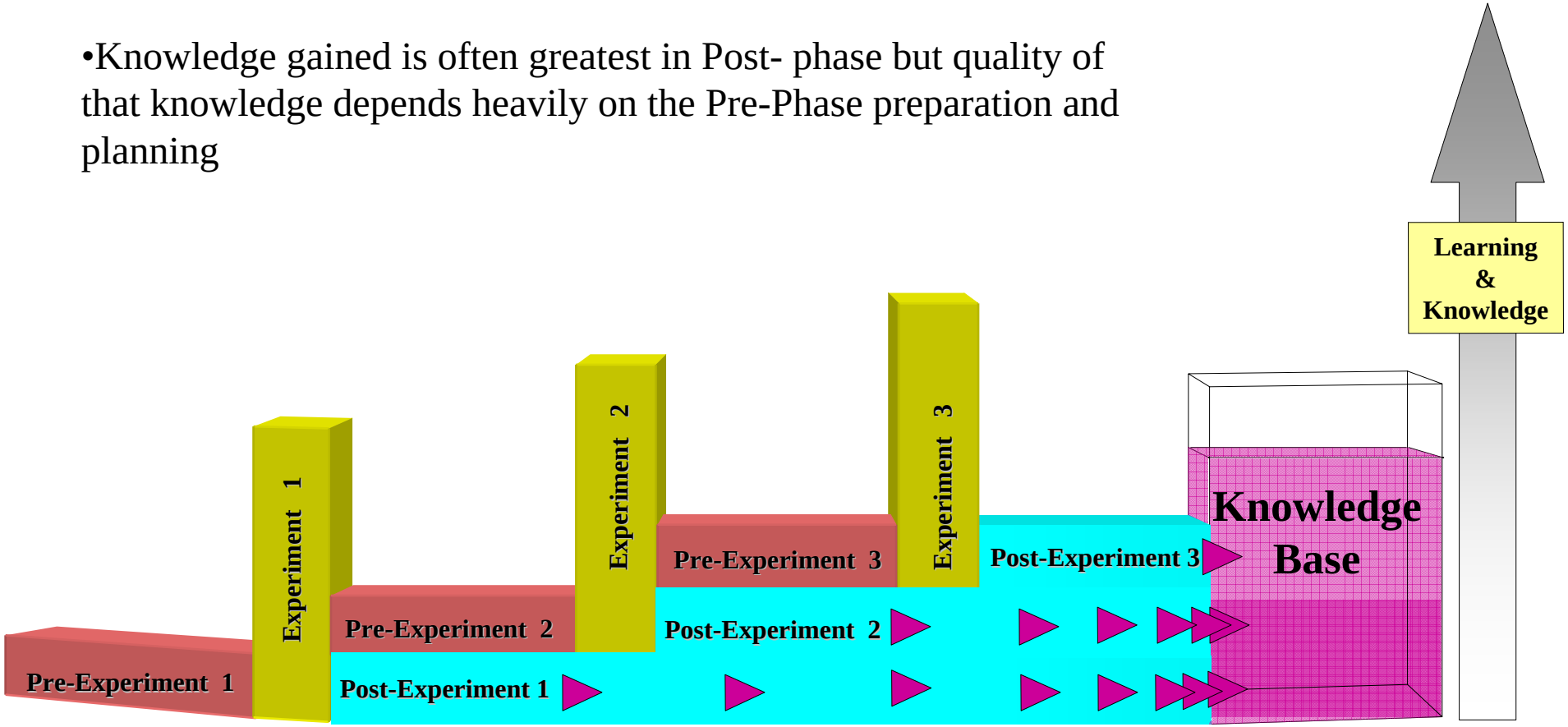
Balanced Experimentation



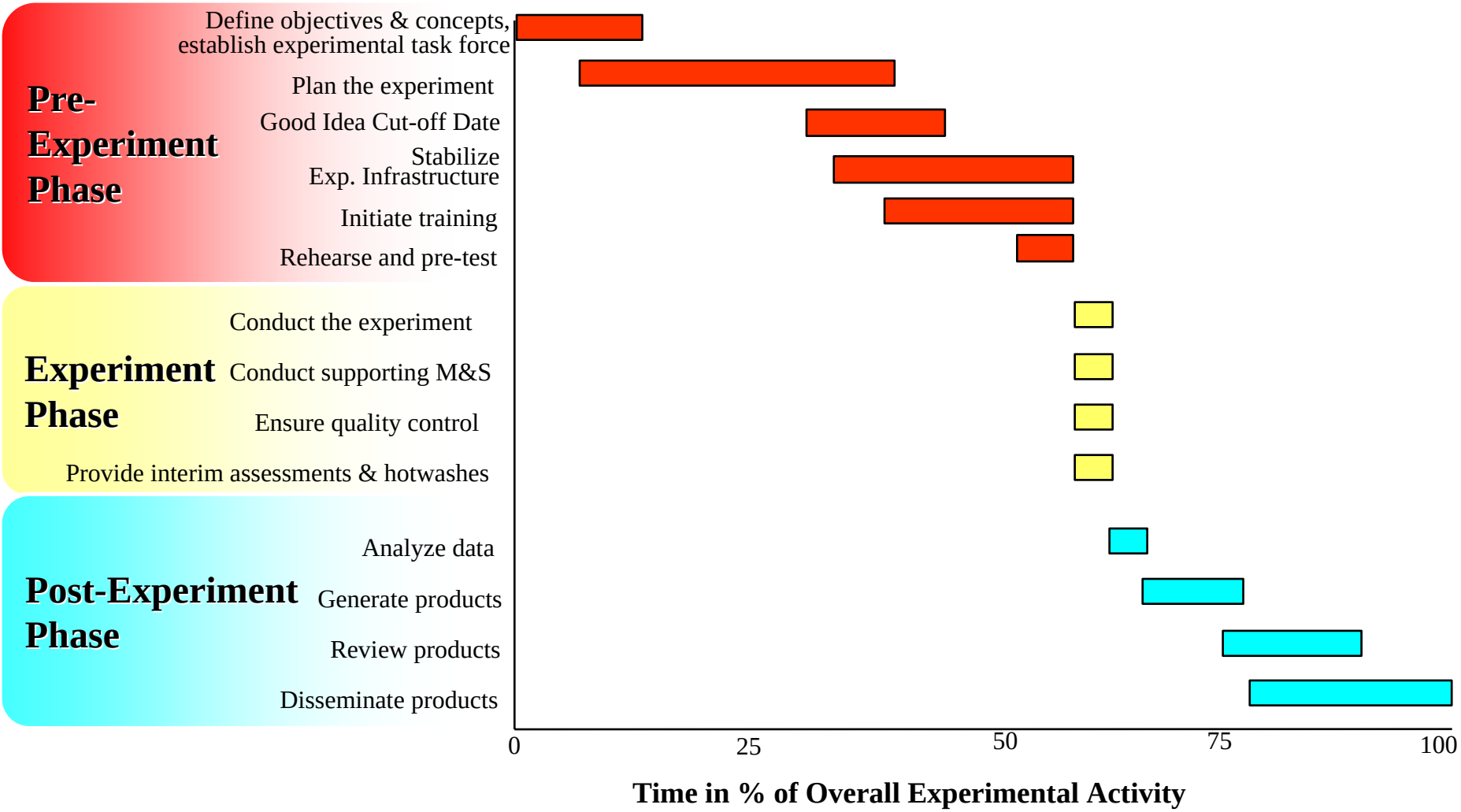
Campaign Plan Concept:
Linked Experiments

•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



Balanced Experimentation

Phases of Activity

MORE

- **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

The Pre-Experiment Phase (2 of 4)

- **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)

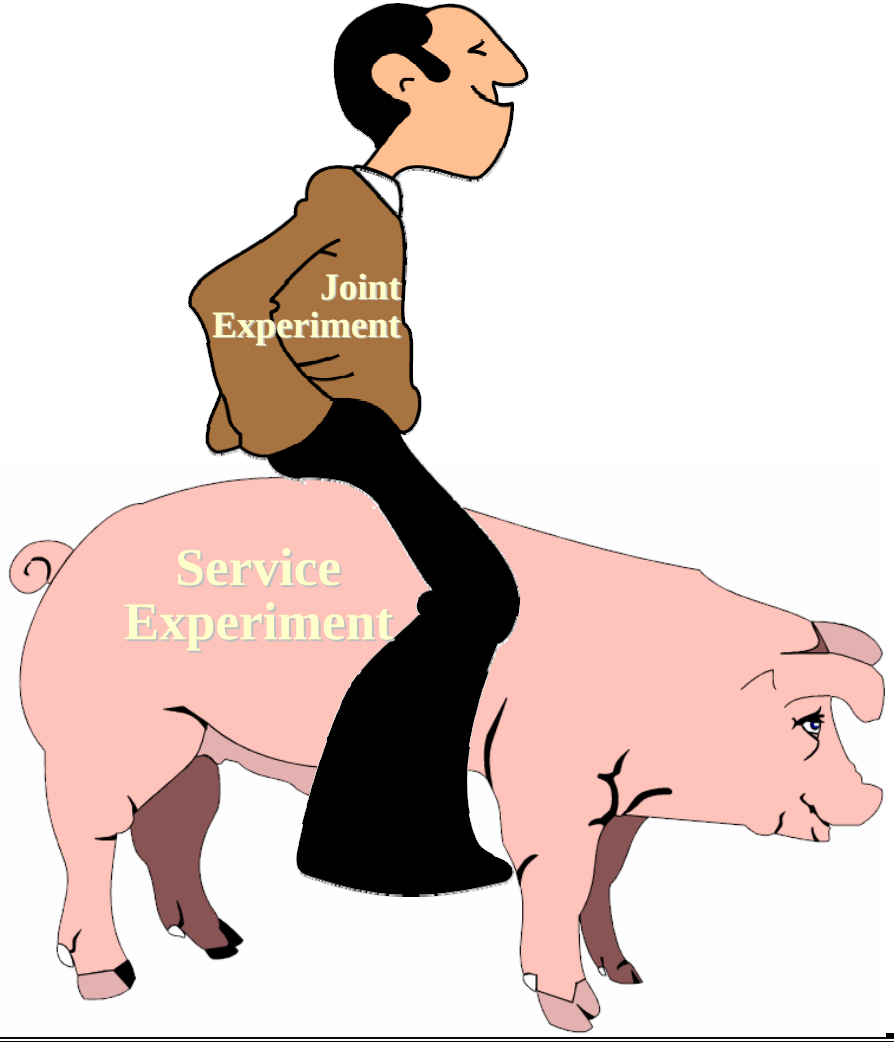
- **Refine/improve M&S**
  - Conceptual
  - Executable
- **Exploit experimental results**
  - Build knowledge base
  - Ensure that “lessons recorded” become “lessons learned”

Code of Best Practice Insights

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)

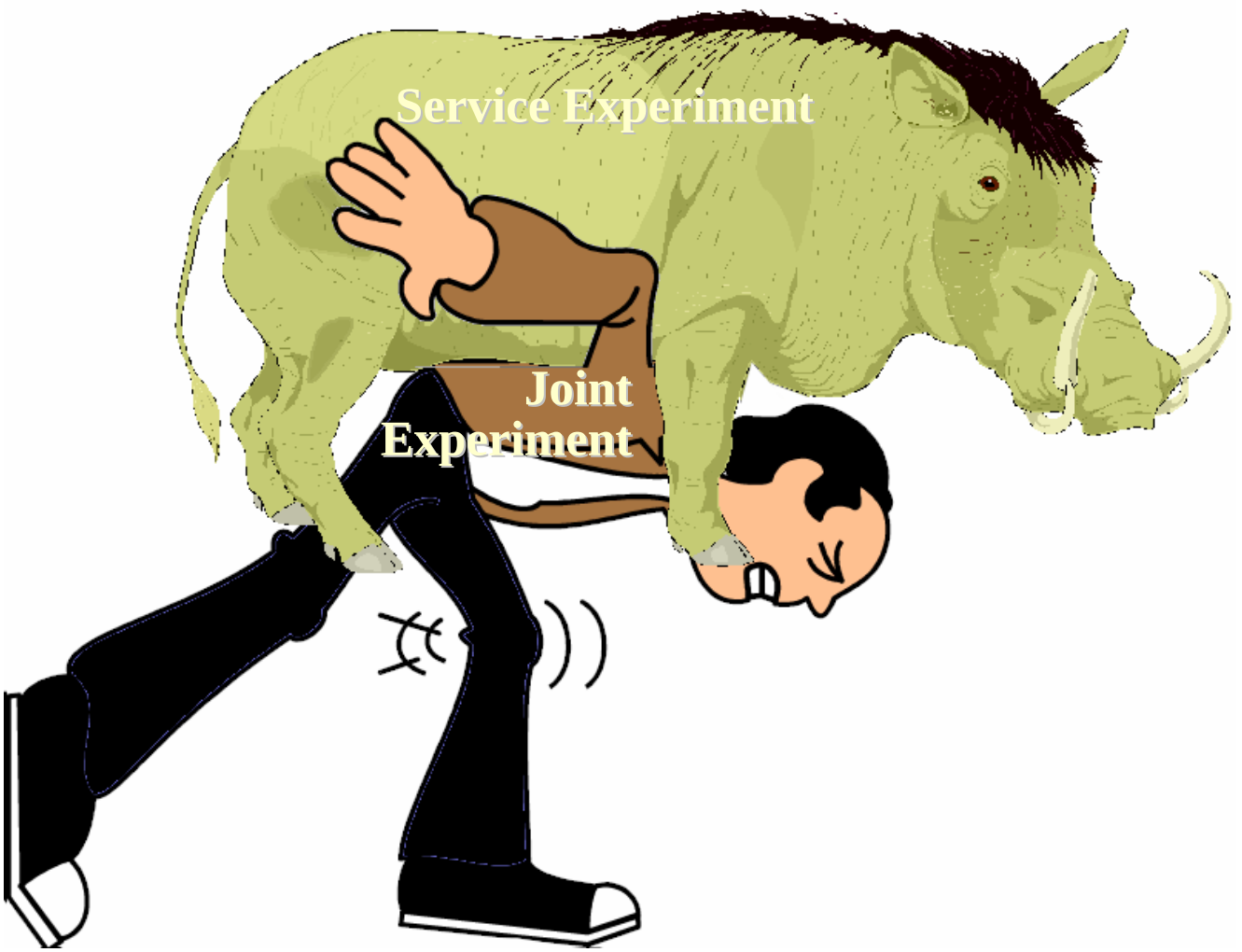
Piggybacking Experiments May Seem Like a Good Idea...



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 1everage 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

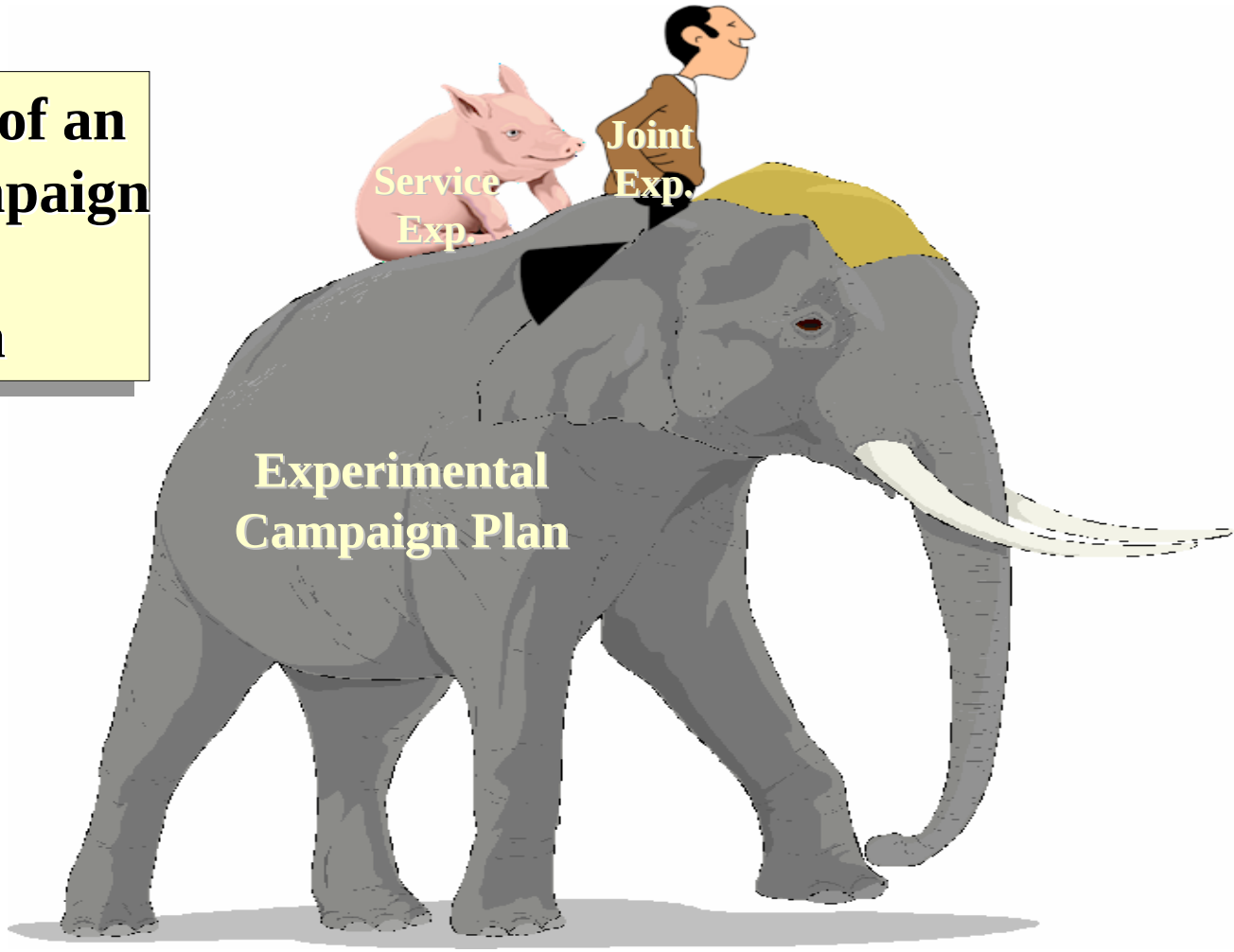


Keith Kirkland:

This is based on Dr. Starr's final outbrief on behalf of the MORS Synthesis committee

A Win-Win Situation

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



Duck Bites Can Kill

MORE

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

ISX Lessons Learned (3 of 4)

- **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

ISX Lessons Learned (4 of 4)

- **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 visitiors
  - 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

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.