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Lessons Learned from the First Joint Experiment (J9901)

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In 1999, the Joint Advanced Warfighting Program (JAWP) at the Institute for Defense Analyses (IDA) conducted with and for the US Joint Forces Command its first joint experiment. This first experiment had multiple objectives. Its substantive focus was on exploring new joint concepts to detect and attack critical mobile targets, specifically theater ballistic missiles. (The description of the experiment design and results is covered in a US Joint Forces Command document, *The Joint Experiment J9901: Attack Operations Against Critical Mobile Targets*, September 29, 2000.) This first experiment also established a base of tools and knowledge to explore a broader set of joint concepts necessary to achieving the ambitious goals of Joint Vision 2020.

In addition, a major objective was to learn about designing and conducting effective joint experiments. I believe that this first experiment was successful in maturing the joint experimentation process by creating a disciplined environment conducive to both *discovery* (what could be) as well as *measurement* (what happened). The attached paper offers a menu of insights and observations that the JAWP team gleamed from its experiences with J9901 (which relied heavily on human play in a computer-generated synthetic environment). I hope it will be helpful to others charged with the task of designing and conducting future experiments.

I invite your comments and feedback, which should be directed to:

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Preface

This document was prepared for the Director, Defense Research and Engineering, in the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, under the task order Joint Advanced Warfighting Programs (JAWP). It addresses the task order objective of generating advanced joint operational concepts and joint experimentation to assist the Department of Defense in attaining the objectives of Joint Vision 2020. Members of the JAWP contributed to the ideas and review of this document. Other contributors included Dr. Ronald A. Enlow, Dr. John E. Morrison, Dr. Dennis F. DeRiggi, and Mr. George E. Lippencott.

The JAWP was established at the Institute for Defense Analyses (IDA) by the Office of the Secretary of Defense and the Joint Staff to serve as a catalyst for stimulating innovation and breakthrough change. The JAWP Team is composed of military personnel on joint assignments from each Service as well as civilian analysts from IDA. The JAWP is located principally in Alexandria, Virginia, and includes an office in Norfolk, Virginia, that facilitates coordination with the United States Joint Forces Command.

This document does not necessarily reflect the views of the Institute for Defense Analyses or the sponsors of the JAWP. Our intent is to stimulate ideas, discussion, and, ultimately, the discovery and innovation that must fuel successful transformation.

Recent and Forthcoming Publications of the Joint Advanced Warfighting Program

Taking the Revolution in Military Affairs Downtown: New Approaches to Urban Operations, William J. Hurley, IDA Paper P-3593, forthcoming, February, 2001.

Red Teaming: A Means for Transformation, John F. Sandoz, IDA Paper P-3580, forthcoming, January 2001.

FY2000 End of Year Report: Volumes I, II, and III, Theodore S. Gold et al., IDA Paper P-3571, forthcoming, November 2000.

US Army and US Marine Corps Interoperability: A Bottom-up Series of Experiments, Rick Lynch, Tom O'Leary, Tom Clemons, and Doug Henderson, IDA Paper P-3537, forthcoming, November 2000.

Developing Metrics for DoD's Transformation, Joel B. Resnick, IDA Document D-2528, October 2000.

Experimentation in the Period Between the Two World Wars: Lessons for the Twenty-First Century, Williamson Murray, IDA Document D-2502, October 2000.

Lessons Learned from the First Joint Experiment (J9901), Larry D. Budge and John Fricas, IDA Document D-2496, October 2000.

Military Operations in Urban Terrain: A Survey of Journal Articles, D. Robert Worley, Alec Wahlman, and Dennis Gleeson, Jr., IDA Document D-2521, October 2000.

The Joint Experiment J9901: Attack Operations Against Critical Mobile Targets, Joint Advanced Warfighting Program, September 29, 2000. Prepared for the US Joint Forces Command.

Joint Strike Force Operational Concept, Joint Advanced Warfighting Program, forthcoming, September 13, 2000.

Joint Warfighting Experimentation: Ingredients for Success, James H. Kurtz, IDA Document D-2437, September 2000.

Joint Advanced Warfare Seminar, James H. Kurtz, Daniel E. Moore, and Joel B. Resnick, IDA Document D-2346, July 1999.

Workshop on Advanced Technologies and Future Joint Warfighting, April 8–10, 1999: Summary of Proceedings, William J. Hurley, Phillip Gould, and Nancy P. Licato, IDA Document D-2343, May 1999.

Framework for Joint Experimentation—Transformation's Enabler, Karl Lowe, IDA Document D-2280, January 1999.

Contemplating Military Innovation, IDA Document D-2191, Dennis J. Gleeson, August 1998.

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1. Introduction

1.1 Background

On May 15, 1998, the Secretary of Defense designated the Commander-in-Chief of the US Joint Forces Command (formerly US Atlantic Command) as his executive agent for joint warfighting experimentation. Joint Forces Command assumed the mission on October 1, 1998.

Between October 1998 and August 1999, the Joint Advanced Warfighting Program (JAWP) at the Institute for Defense Analyses (IDA) designed, prepared, and conducted the first joint experiment for Joint Forces Command under its new charter. The experiment received the designation as Joint Experiment J9901: Attack Operations Against Critical Mobile Targets. The J9901 experiment had three major objectives:

- Explore a new concept for attacking mobile targets. The essence of this "Attack Operations" concept was an adaptive command and control (C2) arrangement that employed a sufficiently dense and diverse suite of sensors, coupled with responsive weapons, to enable the anticipation, tracking, and targeting of these elusive targets.
- Serve as an exemplar to increase the understanding of how to conduct joint experiments, including the use of human-in-the-loop (HITL) simulations, that can produce breakthrough changes in future joint force capabilities.
- Lay a groundwork (tools, people, and knowledge) for diverse future experiments, especially joint C2 issues.

Joint experimentation is a new endeavor—thus, it is not surprising that there are a variety of views about what it is and how to do it. Two attributes in particular characterized J9901. It featured HITL within a synthetic environment. It also emphasized discovery and learning, not only allowing but encouraging adaptation and innovation by the players over the course of the experiment. Not all future joint experiments will feature these aspects as prominently. Some of the observations relate specifically to these two features; most, however, are more general in nature.

1.2 Purpose of This Document

This document offers observations and lessons learned about the methodology and processes used in preparing for and executing the Joint Experiment J9901. Another document, *The Joint Experiment J9901: Attack Operations Against Critical Mobile Targets*, separately covers the results of the experiment.[1] The *J9901 Experiment Design Document,* the *J9901 Experiment Management Plan*, and the *J9901 Trials Repository* all contain additional documentation, including the design and implementation of the experiment.

The primary focus of these observations and lessons learned is to assist those involved in designing and conducting future joint experiments. Even with this audience in mind, some of the observations may appear to fall in the category of "the obvious." They were included because, retrospectively, many were not obvious to the JAWP team at the time they were putting J9901 together. We note four principal lessons learned:

- The operational concept is the heart of the experiment and should remain so throughout the entire process. The concept should be described in sufficient detail and early in the process to facilitate its evolution and maturation. The centrality of the operational concept to the experiment can too easily get lost in the press of modeling, simulation, data collection, and all the other necessary supporting activities.
- Human behavior is an essential component of warfare, and thus the joint experiment must capture this human dimension. Experiments about joint C2 (largely about decision making) should have the support of HITL simulation tools. (J9901 showed the practicality of the HITL simulation tool in joint experimentation.)
- There is a need for a top-notch simulation team along with the simulation tools. One cannot do successful joint experiments with a "pick-up" simulation team.
- An adaptive, thinking, and creative Red Team is critical. Considerable time and resources are required to make this happen.

1.3 How to Use This Document

Chapter 1 presents an overview of the background, tasking given to the JAWP, and highlights the four principal lessons learned.

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[1] Published September 29, 2000, and is available at http://www.jfcom.mil/j9/Events/J9901.htm.

Chapter 2 presents a brief overview of the joint experimentation process, discusses the phases that make up the process, and describes the JAWP team's approach to the design and conduct of the J9901 experiment.

Chapter 3 presents a compilation of comments that provide observations and lessons learned about joint experimentation in general—and J9901 in particular. These include things that went well and things that did not go well. The comments represent the collective judgment of the team that conducted J9901. All were intended to help future experimenters, including those without extensive military or joint experimentation experience.

The appendix contains a more detailed description of the J9901 Experiment. References and acronyms are provided at the end of this document.

2. Designing the J9901 Experiment

This chapter presents a brief overview of the joint experimentation process, discusses the phases that make up the process, and describes the JAWP team's approach to the design and conduct of the J9901 experiment.

2.1 The Joint Experimentation Process

The experimentation process is depicted in Figure 1. A description of each phase of the process follows.

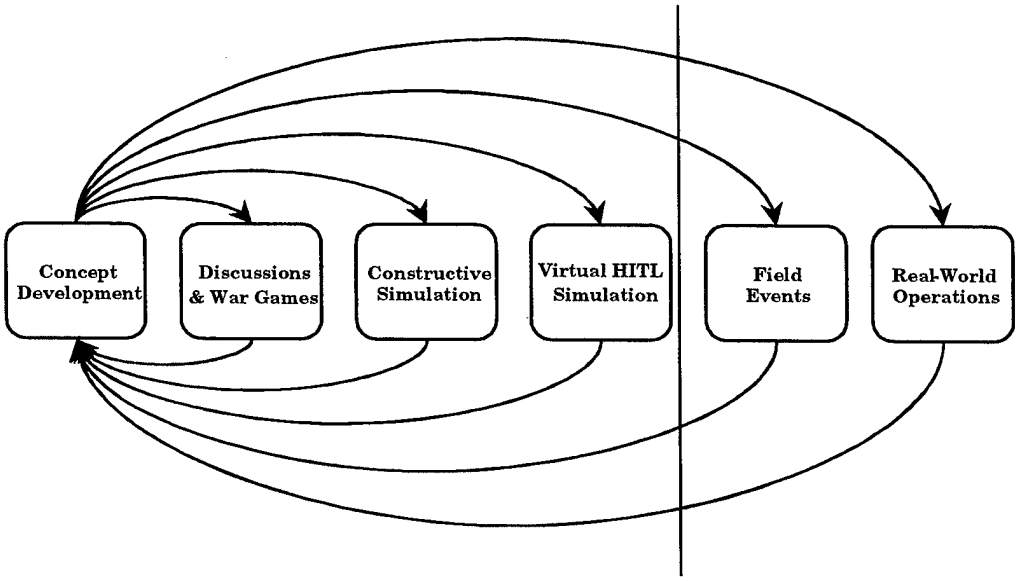

Figure 1. Experimentation Process

CONCEPT DEVELOPMENT. As discussed in the US Joint Forces Command report on J9901, the joint experimentation process used was iterative, beginning with the initial concept development.[2]

[2] The experimentation process depicted is intended to be flexible and is not linked to a set series of detailed procedures and functions. Consequently, Figure 1 serves primarily as an illustration of the overall process and should not be interpreted as a formula for a step-by-step methodology. It also serves to aid the process of discovery in a disciplined manner.

DISCUSSIONS AND WAR GAMES. Once initially developed, participants evaluated the concept in seminars and simple tabletop war games. The goal was to ensure that no "show-stoppers" were evident in the concept at the beginning of the process. As a result of the seminars and war games, changes were made.

CONSTRUCTIVE SIMULATION. The next step in the process was a more in-depth look at the concept using a constructive simulation that could identify possible strengths and weaknesses as well as provide additional insights. Refinements were made to the concept. These included setting the initial parameters and numbers for sensors and other systems used in the virtual HITL simulation.

VIRTUAL HITL SIMULATION. This phase introduced human players into the experiment, which allowed for the following:

- exploration of human ability to manage the concept,
- investigation of the dynamic interaction between opposing forces (Blue vs. Red),
- assessment of human contribution to the concept, and
- identification of weaknesses and/or improvements to the concept.

PHASES NOT INVOLVED. The remaining two possible phases in the experiment process could involve live field events and actual real-world operations, but J9901 did not continue further in the experimentation process because of time, personnel, and funding constraints. Additional analysis, constructive simulation, and HITL simulation would then follow these.

NOTE: At any point along the process, the concept could have been redesigned or reworked. Failure of the concept was an acceptable outcome because even failure provides for discovery and learning.

2.2 The J9901 Approach

The J9901 experiment was concept based and used a Red Team whose job was to defeat the concept with forecasted adversary technology, tactics, and techniques. The goal was not to specifically attempt to either control independent variables or conduct trials of sufficient numbers to be able to provide statistically significant data. J9901 was a heuristically guided

investigation to support discovery and innovation.[3] The focus was on learning how to conduct attack operations and not on evaluating how many pieces of a particular system one might procure for this mission.

Several factors drove the specific experiment approach and design of J9901:

- First, it represented the beginning of a new experimentation program; consequently, there was a need to investigate ways to do future experiments.
- Second, the specific problem selected—attack operations against theater ballistic missiles (TBMs)—represented an enduring problem.
- Third, there were several previous efforts dealing with the problem that provided a wealth of knowledge and information for experiment development.
- Finally, the Joint Semiautomated Forces (JSAF) program offered the HITL modeling and simulation tools for building an experiment that looked into the future.

The availability of resources impacted the design and conduct of the experiment—principally time, funding, and personnel. The US Joint Forces Command required that the JAWP conduct the experiment, from concept development through trial execution within Fiscal Year 1999 (October 1, 1998, through September 30, 1999). **These resource constraints, however, did not prevent the execution of an effective first joint experiment.**

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[3] See D. Robert Worley, *Defining Military Experiments,* Institute for Defense Analyses, Alexandria, VA, February 1999.

3. J9901 Experiment: Lessons Learned

This chapter presents a compilation of observations and lessons learned about joint experimentation, based on the J9901 experience. The comments represent the collective judgment of the team that conducted J9901, and cover both successes and shortfalls in the J9901 experimentation process.

We have organized this compilation into the following 11 areas that would have to be addressed by those designing and conducting future experiments:

- Experiment Schedule
- Concept Development
- Experiment Design
- Discussions and War Games
- Training
- Modeling and Simulation
- Red, White, Blue, and Gold Teams
- Experiment Execution
- Assessment and Analysis
- The Experiment Team
- Funding and Contractual Arrangements

3.1 Experiment Schedule

Figure 2 depicts the J9901 experiment schedule.

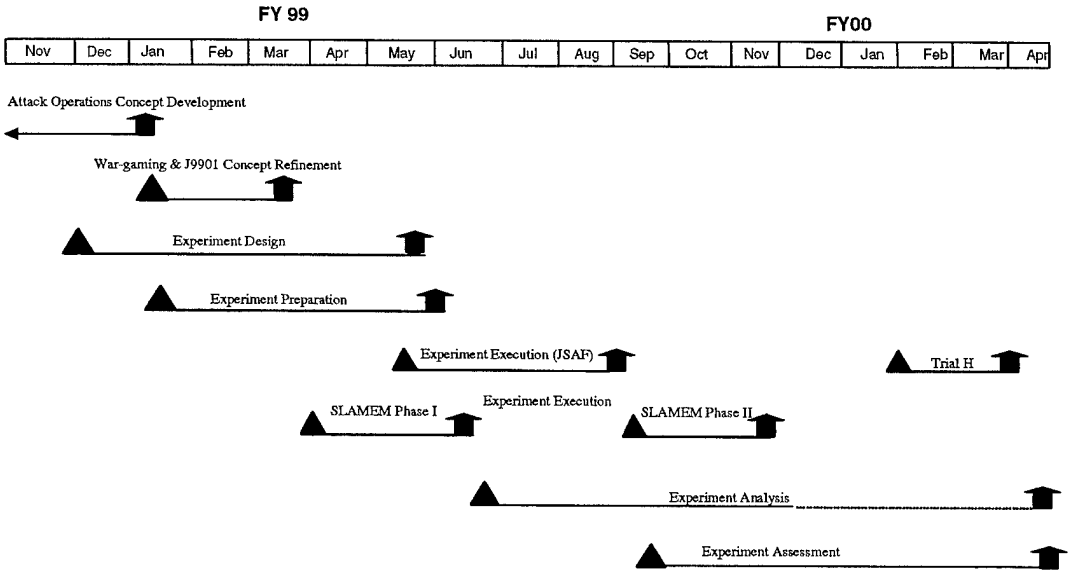

Figure 2. J9901 Experiment Schedule

In view of the given time constraints, J9901 was an ambitious project—from start to finish in less than a single fiscal year. **An experiment of this size and scope should have been executed over an approximately 18-month period.** Numerous tradeoffs were made to accommodate the time window. The additional time—six months—could have been used to develop, prepare, and mature the concept. It would have allowed for additional constructive simulation runs that would have directly benefited and informed the conduct of the actual trials. A longer experiment schedule would have permitted a longer break between trials. This would have enhanced each subsequent experiment by allowing changes to be made in the simulation to accommodate emerging insights or fix problems encountered.

In general, time will likely be the most precious resource, and too little of it will be available for in-depth exploration of complex concepts. Therefore, the concept development and experimental design teams must be explicit in defining an experiment's focus that is compatible with the time available. They must also provide a credible context for this focus that establishes hooks to other ongoing and future experiments. In J9901, for example, robust air defenses and the need for extensive joint suppression of enemy air defenses (JSEAD) were assumed away and their effects left for subsequent experimentation.

Experiment milestones must be established early. The schedule must include plans for in-progress reviews, holidays, travel, set-up time, VIP visits, etc. The process of "discovery" experimentation also demands an adaptable schedule; therefore, flexibility is key throughout the planning process or else experimenters will be forced to work at an impractical pace.

Experiments on significant issues will naturally draw interest from audiences outside the experiment and generate requests to visit and observe the experiment while it is underway. This requires planning to provide both for quality exposure of the experiment to the visitors while simultaneously ensuring their presence does not disrupt the experiment. **The issue of visitors must be addressed early to ensure that important audiences have the opportunity to schedule their visits in a fashion that is manageable and that the design of the experiment (both layout and process) can accommodate their presence.**

Early identification and coordination of simulation and facility requirements are essential. J9901 was fortunate to be able to utilize (1) an existing simulation (the Syn-

thetic Theater of War Advanced Concept Technology Demonstration (ACTD), subsequently renamed JSAF) and (2) a sponsoring facility, the US Joint Forces Command's Joint Training, Analysis and Simulation Center, to conduct an activity that had not been factored into anyone's long-range planning. Such good fortune should not be anticipated for future experiments.

In developing an experiment schedule that crosses fiscal-year boundaries, provisions are necessary to ensure adequate funding is available across the fiscal-year boundary. Provisions can be made to ensure continuity and a smooth transition between fiscal years. On the other hand, a lack of planning could cause significant problems, such as the inability of participants to travel because of the temporary unavailability of TDY funds.

3.2 Concept Development

Before the development began, the J9901 Team was assisted by the fact that attack operations were already receiving significant attention within the Defense community, with several studies extant or underway. The team putting the J9901 concept together used these studies and activities to gain credibility and to leverage the work already completed.

Although J9901 involved research into technology programs at the Defense Advanced Research Projects Agency (DARPA), the National Laboratories, the Lincoln Laboratory at the Massachusetts Institute of Technology, and some commercial firms, the team did not cast its net wide enough. If time had been available, further attempts could have incorporated Service laboratories and other academic institutions. **In future experiments, there is a need for several technical symposia to bring together interested parties from academia, government, and commercial sources to ensure that the best information is available to concept designers.**

The presence of a high-level advocate or stakeholder during concept development and implementation would have helped the Concept Development Team over the inevitable obstacles in the way of achieving a full and comprehensive understanding of a mission area. The presence of the stakeholder is also necessary to ensure that outcomes of the experiment will find their way into the transformation process.

Concepts should not be set in concrete at any point during the experiment. In J9901, a more detailed concept evolved over the course of the experiment, based on the dis-

covery and learning that took place from trial to trial. This would not have occurred had a more rigid approach been taken.

Although concept development, experiment design, and simulation designs are logically sequential and separate, in fact, they are functionally interdependent, overlapping, and iterative. Nevertheless, concept development should be the driver. **Concept development must occur first to provide direction.**

During the experiment development phase of J9901, the Concept Development Team focused most of its efforts on sensors, weapons, automatic target recognition (ATR), tracking, and fusion. However, even though innovative joint C2 was an essential element of the concept, serious attention to C2 issues was delayed until later in the process. Consequently, requisite efforts were not devoted to the development of C2 displays and decision aids, particularly the capabilities resident in future workstations and the organization of the Critical Mobile Target Cell (CMTC). We were fortunate that the JSAF simulation team did cover this area on its own initiative. **Command and control will likely be central to future joint experiments and should be considered up front.** The Concept Development Team needs to devote time and energy to the areas of displays and decision aids to ensure that realistic future capabilities, including human-computer interfaces (HCIs), are built into the C2 system from the beginning.

The Red Team cannot limit itself to merely asking the intelligence community for the requisite estimates. **The Red Team must work with technologists, academia, the National Laboratories, and even commercial firms to identify these future capabilities. The Red Team should cast its net widely, identify sources of expertise, and keep these sources available during the experiment. The Red Team must contain its share of the best people available.**

Close interaction with the Services can enhance joint experimentation. Service interaction was not extensive in J9901 and came primarily in the form of concerns for why particular Service programs were not represented. **Consideration should be given to greater Service involvement in future experiments, with the most desirable course being their involvement throughout the process from beginning to end.**

3.3 Experiment Design

The experiment design must be flexible to deal with surprises, changes in the concept, radical shifts in technology, as well as innovative Blue or Red tactics and doctrine.

In J9901, assumptions made during the design phase had an effect on the whole process of experimentation. Examples include assumptions about probability of detection, automated tracking and ATR performance, sensor false alarm rates, and weapon performance. Some time and effort need to be dedicated to understanding these assumptions and their impacts on the experiment. For example, the assumption of a low false alarm rate would significantly impact sensor performance. On the other hand, setting the false alarm rate too high would significantly alter the results. **The constructive simulation phase can be invaluable in identifying and understanding the potential impact of assumptions such as the sensor false alarm rate, sensor area coverage, and ATR performance.**

In J9901, each trial (except for Trials F and H) covered a 24-hour period. Because of resource constraints, it was a challenge to set up runs of 24-hour duration. Nevertheless, it was understood that this timeframe was not long enough to experiment fully with the concept. For example, a 48- or even 72-hour period would have allowed for a greater exploration of the impact of attacking TBM infrastructure and logistics. **Longer trial periods would also have allowed for better understanding of the impact and use of long-dwell sensors.**

The basic concept and design for the experiment need to be developed and documented in as much detail as possible—and as early as possible—in the *Experiment Design Document*. Subsequently, the concept and experiment design can adjust as planning proceeds, and can be changed as late as the beginning of the trials.

Advocates for the key components of the concept must be identified early to ensure that the capabilities of their components are accurately simulated and utilized during the experiment. Examples of these key components include sensors, C4I systems[4], and weapons. Every effort should be made to keep these advocates engaged and involved throughout the experimental process.

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[4] Command, control, communications, computers, and intelligence.

The experiment's data collection and analysis plan (DCAP) is an integral part of the design. It cannot be created retroactively.

In J9901, analysts largely created the DCAP because they were more familiar with the analytical process. **The team putting the DCAP together should have also included members with experience in military operations, intelligence, missile threats, sensors, and weapons.** This would have led to a more effective DCAP and would have allowed for other members of the team to become familiar with and understand the DCAP development process and its impact on the experiment.

The experiment design must include multiple trials to fully explore the concept. However, determining the number of trials is difficult. In J9901, the decision was for two rehearsal trials and seven record trials (the first two of which were less useful because of problems with data from the After Action Review System (AARS)). **More use of the constructive simulation to explore the concept in more detail prior to the HITL trials would have provided a better basis for selecting the number of HITL trials.**

Selecting the parameters to vary in the experimental trial will present a challenge to the experiment designers. The nature of most experiments—their complexity and two-sided human involvement—will make it difficult to isolate single variable causality. The use of constructive simulations (even more extensively than we were able to do in J9901) that are closely linked to the HITL trials can help in shedding light on these relationships. Another complication arose during J9901 and will likely again in future experiments. During the course of the experiment, plans will change and parameters and variables will need to be adjusted—sometimes even during an individual trial. The reasons range from problems with the simulation and models to reacting to what is being learned during the experiment. We strongly suggest that a process be established before the trials start to deal with these "unexpected" changes, and to consider the alternatives and consequences.

More wargaming of the operations concept, using outsiders who have operational expertise, is useful for identifying and correcting problem areas. This did not occur because of time constraints. Problem identification and fixes had to be made during the trials. Additional wargaming could have prevented this. For example, there were no provisions for the timely reporting of battle damage assessment (BDA) to the players. This became a central issue for the players after the first two trials. BDA

reporting was added and required the dedication of an individual to provide "manual" feedback to the CMTC during the remaining trials.

Security planning must play a major role from the beginning in the design and conduct of an experiment. Even unclassified experiments need to prepare security guidelines. The absence of proper security policies and procedures can delay or disrupt the experiment. Classification policies and procedures, including requirements for classified communications support and security clear procedures for visitors, need to be drawn up at the beginning of the experiment design process.

There is a need for long lead-times to get approval for foreign officer participation in any Department of Defense (DoD)- or Service-sponsored military experiment. The clearance and approval process must begin immediately once it has been determined that allied military or personnel from other foreign government agencies will participate in the experiment.

3.4 Discussions and War Games

Early detailed discussion is an essential step for defining the concept, identifying the key issues, selecting the appropriate experimentation tools, and identifying expertise and resources. In addition to much internal discussion, there were two organized discussion sessions involving outside personnel. The first, hosted by the Joint Theater Missile Defense – Attack Operations Joint Test and Evaluation, occurred at Kirtland Air Force Base, New Mexico; and the second, which included representatives of the National Laboratories, at IDA. Although these sessions were very useful, there were only two, and these were limited in scope. Additional sessions with a more inclusive group probably would have been useful in "fleshing out" the overall experiment.

Because of limitations on time, there was no formal wargaming conducted in preparation for J9901. **Several war games involving operational players would have been useful.** However, if the right players are not selected, i.e., those who are capable of thinking "outside the box," there is a danger that "breakthrough" concepts will be overlooked in favor of doing things in line with current practices.

Several "Transparent War Games" prepared the Red Force for the experiment. These war games consisted of iterative open sessions by the Red and Blue Design Teams to understand each other's concepts and devise possible countermeasures. **The**

Transparent War Games were helpful in fleshing out each side's tactics and ensuring that the simulations could model them.

3.5 Training

There is a need for a training plan tailored to the players. The experience level of the players must be considered in the length of the training. In J9901, the time allocated for training—two weeks—was not sufficient. Based on player observations during the early trials, more time would have been profitable for hands-on training.

In J9901, software developers were needed for effective training. Their contribution was significant and provided a critical enhancement to the quality of training. This benefit, however, must be balanced with the opportunity lost for their primary duty of software development. **Consequently, care must be taken to ensure there are sufficient people dedicated to the training role and software development to prevent interference with either the accomplishment of the training mission or the timely delivery of software.**

Discovery experiments, by their very nature, are dynamic and require flexibility to maximize the learning experience. One should expect to make adjustments and refinements during the experiment. Additional training most likely will be required as a result of the adjustments and refinements. **Therefore, training must be planned as a continuous process.**

Assessors running the assessment system, members of the Red and Blue Teams, simulation operators, experiment controllers, and individuals conducting VIP briefings must receive training to understand the experiment and supporting systems. **Training time to accomplish this must be integral to the training schedule.**

The collection, development, and archiving of quality training materials and products are significant efforts in their own right. They must start early and can end up driving production of substantive aspects of the experiment. The limited time available to develop J9901 made this a hectic and high-risk operation. In contrast, the training for Trail H in April 2000 benefited significantly from the experience and materials gained in the conduct of earlier trials. This reinforces the importance of archiving experiment materials from experiment to experiment that may have utility more than once.

3.6 Modeling and Simulation

Human behavior is an essential component of warfare and, consequently, of joint experimentation. Entity-level HITL simulation, as demonstrated in J9901, permitted the exploration of the human dimension of the concept. **J9901 further underscored future need for high fidelity HITL simulations as an essential component of joint experimentation.**

Based on the J9901 experience, **simulations for joint experimentation should:**

- **have a modular structure,** enabling easy modification of the scenario, concept of operations, simulated forces, systems, technologies, and data;
- **be iterative and/or adaptable,** allowing shifts from constructive to virtual to war games to seminars to mixed environments as new questions emerge;
- **be quick turning,** keeping up with the constant shift of Red and Blue tactics, and emphasizing the approximate right answer rather than the precise, incomplete (and often wrong) answer;
- **be High-Level Architecture (HLA) compliant,** capable of federating with joint forces and/or capabilities that are live, virtual, and constructive models; and
- **undergo verification, validation, and accreditation** for future innovative concepts based on operational judgment and reasonableness.

Validation and verification (V&V) of entity and model performance are one of the most demanding and time-consuming aspects of using modeling and simulation in experimentation. It should start early with the identification of the appropriate subject matter experts who will eventually validate the effort and seek continuous involvement throughout the design and development of the experiment. V&V of future concepts, technologies, and tactics must necessarily rely heavily on operational judgment because, in most cases, the systems do not exist and/or the concepts have not been tested. V&V must take place at least six weeks in advance of the start of trials so that corrective action may be taken without delaying the start of the experiment. It should have been done in more detail and earlier in the process.

A Modeling and Simulation Annex to the Experiment Design Document is essential. This annex should include a *Model Requirements Document* that lays out in great detail the requirements for the simulation. The *Model Requirements Document* must

contain a Joint Entity List that describes each entity in the simulation and the behaviors and characteristics associated with that entity. This documentation is necessary not only for V&V but also for the post-experiment analysis.

In J9901, there was a significant requirement for performance data to enable the simulation developers to model the software objects representing such components as new weapons systems and sensors. To keep simulation development on schedule, this performance data must be available to the simulation developers at least 90 days prior to integration testing. The performance characteristics must have documentation to support the simulation V&V. In J9901, this was handled by the development of a Joint Entity List that contained the detailed performance characteristics of each of the systems modeled in the experiment and details on how these characteristics were represented in the software.

3.6.1 Virtual HITL Simulation

For simulated experiments, a quality simulation team is absolutely essential. This team must be capable of operating the simulation and making fixes and improvements as needed in a short period of time. Ideally, the simulation team should also include the developers who built the version of the simulation used for the experiment. In J9901, the JSAF Team had been together for at least four years and had participated in two major simulation exercises. The developers who were part of the team were thus able to make changes in a timely fashion and anticipate requirements in advance. **You cannot do successful joint experiments with a pick-up simulation team.**

JSAF was the best available simulation to meet the J9901 HITL simulation objectives. It was, however, difficult to change the scenario or templates given the time constraints of the experiment. **Because discovery experiments invariably lead to changes in the simulation, either the model needs to be flexible or the supporting programmers need to be flexible.**

Simulations used in joint experimentation must have the support of extensive documentation. An alternative is to have the simulation developer available during the experiments to make changes and to troubleshoot problems. In J9901, the Simulation of Location and Attack of Mobile Enemy Missiles (SLAMEM) developers were

available to troubleshoot problems quickly—their presence saved the experiment on several occasions.

In J9901, two weeks were scheduled between trials to make changes to the model and fix problems encountered in the trial. These changes often required a "full court press" by the simulation team so that the changes and fixes would be ready for the next trial. This did not allow enough time for testing the fixes. **Three weeks between trials would have been better.**

In J9901, because of time constraints, there was insufficient time for testing the simulation. Although sub-system testing had gone on for several months, running the full simulation under load only took place in the two weeks preceding the start of training. **The AARS was not run under full load prior to the first trial and, as a result, problems with the AARS corrupted the data from the first two trials.** The problems encountered were not the fault of the JSAF Team or the AARS Team. Both of these teams worked very hard to get the simulation ready in a relatively short time, given all of the changes required to support the J9901 concept.

By its nature, joint experimentation will require significant changes to any existing simulation since new concepts, new systems, new technologies, new doctrines, new organizations, and new tactics are under investigation in every experiment—sometimes in every trial. Experiment designers must allow for this. An optimum solution would be to have the simulation completely ready two months prior to the start of training to provide time for full-up load testing, V&V, and the inevitable fixes and re-testing.

3.6.2 Constructive Simulation

The constructive simulation must be available for concept development work early on. In J9901, there was only sufficient time prior to the HITL trials to use SLAMEM to investigate the sensor and weapons parameters for the HITL simulation, as well as look at the numbers of satellite, unmanned aerial vehicle, and attacks systems required. This simulation, however, did not allow for dynamic interactive play between Red and Blue Forces. Changing Blue and Red systems and responses could not be done on the fly.

In J9901, federating the JSAF simulation and the SLAMEM constructive simulation worked well.

3.7 Red, White, Blue, and Gold Teams

The concept of an adaptive opposing Red Force is vital to discovery experimentation. Consequently, the Red Force must retain a significant degree of freedom to operate and make independent decisions. In J9901, however, the Red Force did not possess a total free rein on its actions. Rather, Red actions were closely coordinated between the Red Team Leader and the White Team Leader to meet experiment objectives and to avoid unnecessary disruptions.

The Red Team had two primary functions: (1) to help develop "counter concepts" and define future adversary capabilities, and (2) to serve as the reactive opposing force during the trials. The work done by the Red Team occurred without benefit of allied or foreign inputs. Thus, potential adversary cultural and other biases were not reflected. **Getting inputs from allies or members of other foreign militaries, as well as getting foreign role players on the Red Team, would be very useful in future experiments.**

J9901 focused on future capabilities circa 2015. **It is vital that both Blue and Red Force capabilities reflect the same time frame.** (There is a tendency to give Blue Force a future capability paired against current day Red capability.)

Experiment control mechanisms need to be established early. These must include controls over Blue and Red Teams to maintain the experiment within agreed bounds. Scenario-tracking procedures also need to be established to meet the experiment's objectives.

In J9901, the White Team was responsible for the overall control of the experiment. The White Team formed late in the concept development phase. Consequently, many of the policies and procedures were formulated late. **The White Team should be formed at the beginning of concept development.** White Team activities include developing the overall control plan and methods for injecting events and altering the scenario, if necessary, to meet experiment objectives.

To conserve personnel resources, members of the simulation team also doubled as members of the White Team. The downside to this arrangement was that their duties sometimes conflicted with their role as members of the White Team. On the plus side, their expertise in simulation was essential to the successful operation of the

White Team function. **Future experiments should avoid the "dual hatting" of the White Team members.**

A Gold Team should be formed early to observe and evaluate the experiment from an external and independent perspective. It should seek insights on both the substance and design to identify flaws or weaknesses to which those closer to the execution may be oblivious. This effort should start early and be continuous throughout the experiment. The goal of the team is to provide constructive criticism to improve both (1) the design and conduct of the immediate experiment and (2) the design and execution of future experiments.

3.8 Experiment Execution

In J9901, the same group of players was retained through the first nine trials of the experiment. Although the experiment designers recognized that there would be significant learning effects over the course of the experiment, they felt that the increased competence of the players would result in their being able to provide valuable insights into the goals of the experiment. This was borne out by the experiment. We were also fortunate in having a number of capable, experienced personnel as players—which underscores the fact that **it is essential to recruit the right players.**

The plan for experiment execution must recognize that the experiment day is longer than just the simulation time. J9901 was designed with the belief that six hours was the maximum amount of time players could effectively sit in front of their terminals. Before and after each day's simulation run, time was needed for a morning situation briefing, bringing up the simulation, training (as required), daily "hot washes" and/or after actions reviews, and planning for next day's activities.

During the development phase of J9901, the major elements of the experiment team and the simulation team were geographically separated from the US Joint Forces Command J-9 elements in Suffolk, Virginia. However, coordination between and among these distributed elements was imperative and required on a regular basis. **The use of a weekly video teleconference between the team members in the Washington area and those in the Suffolk area proved productive.**

The scenario for the experiment required specific key inputs before the beginning of each trial. For J9901, these elements for Blue and Red included the following:

- a force list (including organization, unit structure, and strength);
- a force laydown (examples include C2, unit/platform posture, logistics, position);
- rules of engagement;
- intelligence inputs and intelligence preparation of the battlespace (IPB) products;
- commander's guidance (including priorities, collateral damage limits, and employment criteria);
- mission objectives, constraints, and desired end state;
- operations order; and
- unit and/or force standing operating procedures (doctrine; tactics, techniques, and procedures (TTPs); reporting)

3.9 Assessment and Analysis

In J9901, the players received great latitude to organize themselves in the most efficient manner and to develop the most efficient TTPs to prosecute targets. As a result, **continuous HITL assessment of the players was essential for understanding the changes which the players made and, more importantly, to understand the reasons for the changes.** HITL observers should remain with the players full time to capture their thought processes during the experiment.

For J9901, the plan was for ongoing as well as retrospective assessment and analysis. The tools for the ongoing analysis—including those used by the HITL assessors—were developed late and matured as the experiment progressed. Problems with the AARS during Trials A and B caused an invalidation of those trials because the data collected was corrupted. Consequently, the primary retrospective analysis tool, which was the AARS, came on line late. The AARS improved as the trials progressed. **To avoid these problems, the assessment and analysis processes, procedures,**

tools development, and testing should occur as early as possible before the actual experimental trials.

HITL assessors need to develop a plan and prepare assessment and/or evaluation tools well in advance of the start of the experiment trials. In an HITL experiment, these tools must include a vehicle for assessing the decision processes used by the players. The tools can then be refined as the experiment progresses. Automated tools, and automation in general, can greatly assist in this process.

Very often, as a result of the experiment, the analysts will make discoveries that will require the development of new Measures of Effectiveness/Measures of Performance (MOEs/MOPs) beyond those developed during the experiment design. **Additional flexibility is needed in the AARS to permit analysts to query the database to analyze additional MOEs/MOPs beyond those described in the original experiment design.**

A significant amount of data was collected during J9901. The amount of time necessary to digest and evaluate this data was underestimated. In addition, most of the team worked on another experiment for approximately two months during the analysis and report writing phase. **Consequently, writing the final report took longer than anticipated.**

The Red Cell, as well as the Blue Cell, requires an assessment and data collection plan to understand the changes that occurred in Red TTPs as a result of the Blue efforts. The accuracy of the Red data is also key to understanding the Blue data.

Production of the final report can be enhanced and accelerated if consideration of its requirements is a part of the early experiment design and the report is incrementally drafted during the experiment. Descriptions of experiment activity can be completed prior to the end of active experimentation and can be best formulated while events are fresh in the writer's mind, leaving one less item to deal with during the post-experiment period when attention should be focused on data analysis and findings formulation.

The writing of the final report cannot be left solely to the analysis team. All members of the team should participate in the analysis and the development of the final report.

3.10 The Experiment Team

For J9901, the JAWP Attack Operations Team acted as the top-level integrator of the concept, the simulation, and the experiment. The team did not have enough people or expertise to do all of the detailed work needed and relied on the JSAF Team to bring the pieces of the simulation together and to operate it. **Future experiments will also need a more robust "integration" team that includes experts that can bring together, operate, and manipulate disparate simulations.**

3.11 Funding and Contractual Arrangements

Many joint experiments will last longer than 12 months. **Consequently, there is a need for a multi-year funding profile to ensure that the experiment is not delayed by lack of funds at the end or beginning of a fiscal year.** Funding support that extends beyond a single fiscal year, similar to that of DoD's ACTD program, should be considered for joint experimentation.

In addition to a multi-year funding profile, every effort should be made to **avoid conducting experiments that end at the beginning of a fiscal year.** The programming and budgeting process can have an adverse impact on the experiment. TDY funding, end-of-year funding drills, and having to wait for the allocation of funds for a new year can cause problems.

Because of the short timelines involved in working problems that develop, **a flexible contractual vehicle to support the experiment is necessary.** In J9901, the contracting capabilities provided by DARPA's JSAF program office provided a flexibility. However, if DARPA is not a participant, obviously its contracting vehicles will not be available. Therefore, a flexible contracting vehicle to support joint experimentation should be developed.

Preparation of documentation and reports for J9901 took more resources, time, and personnel than anticipated. Realistic funding and other resources need to be allocated early to this process.

3.12 Concluding Observations

The methodologies and tools used in designing and executing J9901 proved useful. They can be used in future joint experiments comparable to J9901.

The tools and methodologies used need to be evolved and developed further to support the investigation into concepts and problems larger in scope and to support the process of continuous joint experimentation.

Appendix:
The J9901 Experiment Process

J9901 generally followed the process outlined in Figure 3.[5] J9901 did not, however, include live field events or real-world operations. Flexibility allowed movement within the process. In addition, the constructive simulation phase and the virtual HITL simulation phase operated almost in parallel rather than in sequence. This resulted from delays in modifying the constructive simulation, which did not permit the full use of the constructive simulation in concept development. The constructive simulation was, however, used effectively during the concept development phase in identifying sensor requirements and performance parameters.

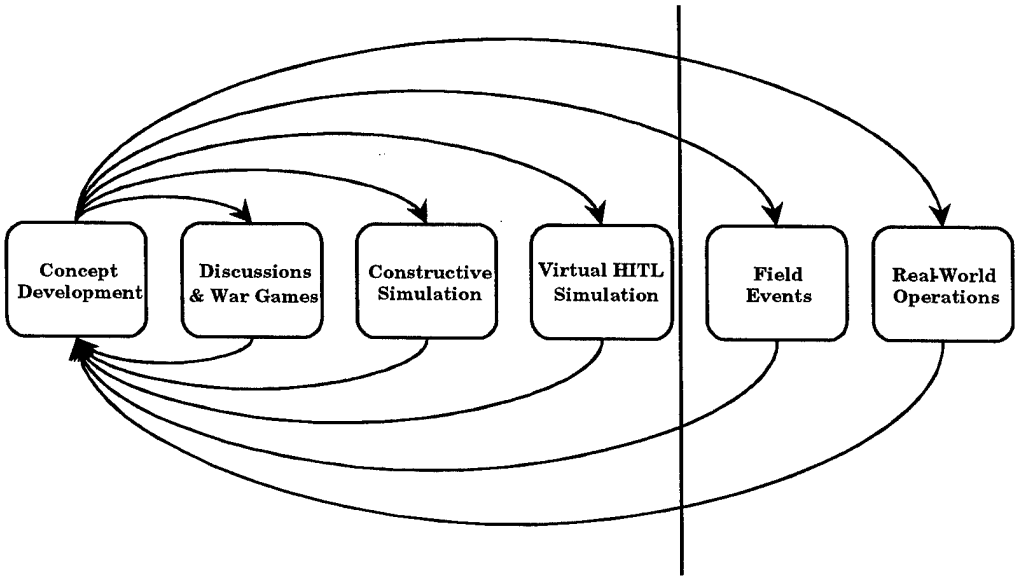

Figure 3. Experiment Process (Reiteration)

The J9901 concept development began with an attack operations workshop held in Albuquerque, New Mexico, in late June 1998. The concept further matured between July and September 1998. During this period the team took advantage of work done previously by the Joint Theater Air and Missile Defense Organization, DARPA, the

[5] We provide Figure 1 here again for the convenience of the reader.

Joint Theater Missile Defense – Attack Operations Joint Test and Evaluation, and the National Laboratories. The experiment concept was briefed to the Deputy Command-in-Chief, US Joint Forces Command, in September 1998.

Data gathering, further concept development, and initial work on the experiment design and the simulation design occurred between October and December 1998. In addition, a Red Team leader was identified, and work on the opposing Red Force began in November 1998.[6] The first detailed simulation design meeting that brought together the planners and the JSAF modeling and simulation team occurred in January 1999. The first meeting with the designers of the constructive simulation also occurred in January 1999. Because of modifications to the constructive simulation, these runs did not begin at IDA until April 1999.

The constructive simulation runs used an existing simulation, SLAMEM, developed by TOYON Research Corporation. SLAMEM served to explore sensor performance parameters, sensor architectures, and concepts for sensor operations for the experiment.[7]

J9901 HITL experimentation began with two rehearsals, conducted between May 3–7, 1999, and May 17–21, 1999. These were followed by a series of seven experiment trials that were conducted between June 7, 1999, and August 27, 1999. An eighth trial (Trial H) occurred in March 2000 using a different group of Blue players. The Trial H players consisted largely of active duty Air Force personnel with experience in Bosnia and Kosovo Combined Air Operations Center operations.

More than 1,000 additional constructive simulation runs using SLAMEM occurred between September and December 1999 to further investigate relationships uncovered during the post-HITL experiment trial analysis effort. Analysis and assessment of experiment results began with the first trial in June 1999 and continued through April 2000.

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6 Additional information on the Red Team is contained in the US Joint Forces Command document, *The Joint Experiment J9901: Attack Operations Against Critical Mobile Targets*, and in a separately published report on the Red Team, *Red Teaming: A Means for Transformation*, IDA Paper P-3580, forthcoming, January 2001.

7 A more detailed JAWP report, *A Constructive Attack Operations Model: Test Results and Analyses*, on the use of SLAMEM and the results will be published separately.

The experimentation process and design are central to the overall joint experimentation program. Using the process described, J9901 was the US Joint Forces Command's first experiment. J9901 represents one approach and can serve as a model for joint experimentation for the following reasons:

- It served to mature the joint experimentation process by creating a disciplined environment conducive to both *discovery* (what could be) as well as *measurement* (what happened).
- It provided substantive insights into the concept under investigation: how to improve attack operations against missile and other critical mobile targets.
- J9901 also established a base (tools and knowledge) for exploring a broader set of command and control and other joint capabilities fundamental to achieving Joint Vision 2010.

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Acronyms

AARS	After Action Review System
ACTD	Advanced Concept Technology Demonstration
ATR	automatic target recognition
BDA	battle damage assessment
C2	command and control
C4I	command, control, communications, computers, and intelligence
CMTC	Critical Mobile Target Cell
DARPA	Defense Advanced Research Projects Agency
DCAP	data collection and analysis plan
DoD	Department of Defense
HCI	human-computer interface
HITL	human-in-the-loop
IDA	Institute for Defense Analyses
JAWP	Joint Advanced Warfighting Program
JSAF	Joint Semiautomated Forces
JSEAD	joint suppression of enemy air defenses
SLAMEM	Simulation of Location and Attack of Mobile Enemy Missiles
TBM	theater ballistic missile
TDY	temporary duty
TTPs	tactics, techniques, and procedures
V&V	validation and verification

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13. ABSTRACT (Maximum 200 words)

In 1998, the JAWP conducted a joint experiment—from concept development through trial execution—for the US Joint Forces Command. This document discusses the joint experimentation process and its phases, including the JAWP Team's approach to the design and conduct of the J9901 experiment. Observations and "lessons learned" are provided about J9901 and joint experimentation in general, as well as for use in future joint experiments. The JAWP Team noted four principal lessons: (1) The operational concept is the heart of the experiment and should remain so throughout the entire process. The concept should be described in sufficient detail early in the process to facilitate its evolution and maturation. (2) Human behavior is an essential component of warfare; thus the joint experiment must capture this human dimension. Experiments about joint command and control (largely about decision making) should have the support of human-in-the-loop simulation tools. (3) There is a need for a top-notch simulation team along with the simulation tools. One cannot do successful joint experiments with a "pick-up" simulation team. (4) An adaptive, thinking, and creative Red Team is critical. Considerable time and resources are required to make this happen.

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