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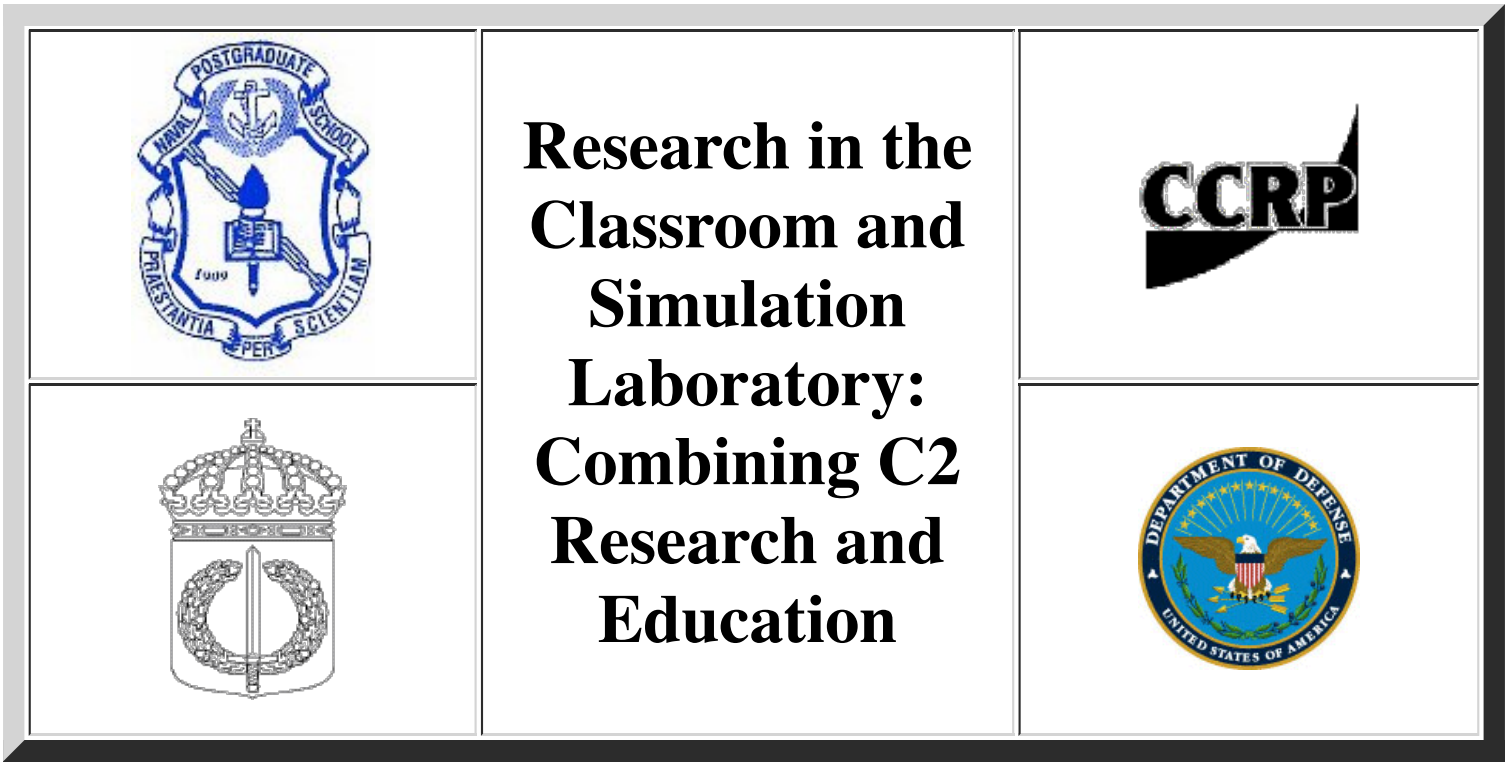

Research in the Classroom and Simulation Laboratory: Combining C2 Research and Education

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Abstract

The ongoing series of ONR sponsored Adaptive Architectures for Command and Control experiments at NPS involves researchers from academia, DOD and private industry and enhances the quality of education provided to NPS student participants. Several NPS courses have been designed, at least in part, to take advantage of the opportunity to involve students in leading edge research, to use the experiments to reinforce knowledge taught in the classroom and to provide the students with a rich thesis environment. The students provide value added on a no cost basis to the A2C2 project by participation in the experiment as players, as Lead Team participants and as thesis students. DOD and the NPS faculty also benefit by association with the A2C2 experiments. This university model that combines research with education for the students, especially with the relevant nature of the A2C2 project, provides a positive result for everyone including the students, the faculty, the researchers and DOD.

1. Introduction

During November 1997, the Office of Naval Research (ONR) sponsored Adaptive Architectures for Command and Control (A2C2) research project conducted the third in a series of Command and Control experiments at the Naval Postgraduate School (NPS). Over the past approximately fifteen years, the Joint C4I Systems curriculum at NPS has developed an experiential learning environment for the officer-students that involves participation in actual DOD research projects sponsored by ONR, DARPA, DISA and others. The officer-students initially take part as players in studies using wargames and simulations as experimental drivers and later by participating in the experimental design, conduct and analysis of these studies. Each experiment, in addition to its intended role as a research tool, provides a rich learning environment, and as a bonus, the participation of the officer-students enhances the actual research.

This paper, using the recently completed A2C2 experiment as a example, will describe how the synergism of integrating the experiment, student participation in the experiment, the Systems Technology Laboratory, where the experiments are conducted, and two of the simulations currently in use at NPS, improve the quality of education for the students while at the same time improving the research efforts for the A2C2 project.

2. Experiment #3

The A2C2 research project follows a model-test-model paradigm to combine theoretical and experimental activities. Hypotheses based on model predictions or results from previous experiments are tested in team-in-the-loop experiments, and in addition, experimental results are compared with a priori model predictions to

improve both the experimental procedures and the models. Following this paradigm, experiment 3 built on experiment 2 to examine the working hypothesis that when faced with a need to adapt their organizational structure, teams would make small changes that led to somewhat better performing structures rather than large ones that led to considerably better performing structures [Benson et al., 1998].

Experiment 3 was conducted at NPS in the Interdisciplinary Academic Center's Systems Technology Laboratory (STL). As in the previous two A2C2 experiments, the Distributed Dynamic Decision making (DDD) III simulation system was used as the exercise driver. The STL and DDD are discussed later in this paper.

3. NPS Student Participation in A2C2 Experiment #3

Sixty-three officer-students, from three different classes, attending three different supporting courses, in two different curricula, took part in the experiment. Fifty-four were experimental participants or "players" and nine others served as the "Lead Team." These roles are described in detail in the [Benson et al, 1998] and [Benson,1998]. Though each class had a different educational objective in participating in the experiment, all shared the common goal of experiential learning.

3.1 CC4103: C4I Systems Evaluation Participants

The CC4103 C4I Systems Evaluation course is required for all students in the Joint C4I Systems curriculum. In it, students learn a systematic approach to C4I systems evaluation, including developing measures of effectiveness. They also survey current techniques for C4I systems evaluation, and expand their knowledge of experimental design. As part of the course, the nine enrolled students served as the Lead Team for A2C2 experiment 3. They participated in the experimental design, scenario modification, planning, developing training materials, conducting player training, managing execution, and data collection. As part of their experiential learning, the CC4103 officer-students also developed their own research questions that could be examined within the design of the A2C2 experiment, formulated hypotheses and measures, collected data to test their hypotheses, analyzed their data, and presented their findings to faculty and their fellow students.

Course Prerequisites are listed below. Descriptions of each can be found in the NPS Catalogue within the

NPS home page at http://www.nps.navy.mil/

OS2103 Applied Probability For Systems Technology (4 - 1).

OS3604 Decision and Data Analysis (4-0)

CC3000 Introduction C4I Systems In DOD (4 - 0).

CC4101 Systems Engineering For Joint C4I Systems (4 - 2)

Material in the courses listed below also helped prepare the Lead Team members for the experiment:

CC2040 INTRODUCTION TO SYSTEM TECHNOLOGIES (3 - 2): Includes introduction to programming with a closed- loop simulation as the term project. The Lead Team served as players for A2C2 experiment #2 (see below).

CC3040 INTRODUCTION TO JOINT C2 SYSTEMS (JCCS) (3 - 3): Includes an introduction to wargaming including hands on use of MTWS, to be discussed in more detail later.

CC2040: Introduction to System Technologies: The CC2040 Introduction to System Technologies course is also required for all students in the Joint C4I Systems curriculum. The sixteen students enrolled in this course were exercise participants. This participation, along with course material, provides these students with an introduction to the concepts of experimental design and the use of human-in-the-loop experiments to evaluate C4I systems and architectures, begins their introduction to the simulations and wargames in the STL which they will use for much of the rest of the curriculum, and helps prepare them for CC4103 when they will be the Lead Group for the next A2C2 experiment.

3.2 MN3105: Organization and Management Participants

The MN3105 course is required for all students in the Department of Systems Management at NPS. Several topics covered in this course were enacted during the A2C2 experiment as the students participated in simulated joint operations through alternative organizational structures. Thus, students had a common experiential opportunity that allowed for the application and analysis of course concepts including: characteristics of high performance teams, decision making, communication, conflict management, organization culture, and organizational structure. The latter topic of structure was the most significant domain of learning from the experiment. As part of the experiment, teams were required to analyze three alternative structures and determine which they thought would be most effective in accomplishing the mission. This decision process challenged students to assess the characteristics of the mission environment and task requirements, and come to a consensus as to which organizational structure they felt would perform most effectively given this analysis. In order to determine best structural "fit," students discussed varying organizational parameters such as centralization, coordination, role complexity, hierarchy, differentiation,

departmentalization, and decision authority.

In addition to the within-experiment application of course topics, the simulation provided an important base for subsequent class discussion and written analysis. This course has historically used case studies as the major pedagogical tool for student learning. Case analysis requires students to apply their knowledge of theoretical concepts to problem solving and action planning relevant to case-based organizational situations. As useful as cases are, they are still somewhat passive. In contrast, the simulation brought the concepts of the course to life in a defense mission environment that students found very engaging. The extrapolation from simulation to real-world application was also reinforced by a written assignment required of all students. This assignment asked students to analyze the environment, tasks, and structural parameters of a joint operational environment, not constrained performance factors particular to the laboratory simulation. The results of this analysis provided some interesting findings that contribute to the generalizability of the A2C2 simulation research. These findings are detailed in [Hocevar, *et al*., 1998]

A final benefit to their participation in the simulation was outside the thematic topics related to organization and management. All students were given both a pre-brief and a post-experiment brief. The former introduced the concepts of experimental design; and the latter explained the research hypotheses, previous A2C2 research findings, and some preliminary results for the experiment in which the students had participated. This introduction to the scientific process provided an important foundation for the thesis research that is required of all students in the Department of Systems Management.

3.3. Relevant Student Education in Conjunction with the Experiment.

Many concrete examples of educational material taught in the classroom were used during the experiment. The students were provided:

> A real life example of an experiment being conducted by professional researchers.
>
> An opportunity to use or observe the principles of war during execution of their scenarios. The principles of war include: unity of command, unity of effort, economy of force, simplicity, and span of control. The objective was to highlight the advantages and disadvantages of the three architectures from the warfighter's perspective [Hutchins et al., 1998].
>
> An opportunity to explore the dimensions of a combat architecture including its authority structure, communications structure and resource coordination structure and how they employed them in a synchronized manner [Benson, 1998].

An opportunity to explore the notion that trying to fit a fixed combat architecture to a dynamic set of tasks may not be the optimal way to successfully complete your assigned mission. Issues related to adaptability that allows change of combat architectures to dynamically fit the circumstance are raised. Basic issues are explored such as what is a better or optimal architecture for the situation? How do you determine better or best? When do you change again or change back? How can you tell that the change was better? How do you train for use of dynamic architectures? How do you inspire confidence and credibility in using them?

An exposure of joint warfare to students from all four services. Since the scenario involved use of air, land and ground forces, students were provided an opportunity to conduct operations in a joint environment. This reinforced joint doctrine material presented in the classroom.

Practical reinforcement of the CINC crisis action planning process that is taught in the classroom. This occurs during preparatory phases of the experiment in which teams are provided OPORDERS with which to plan their mission.

3.4. Student Theses Based on the A2C2 Experiments and Associated Research.

The A2C2 project permits students to be exposed to and work side-by-side with experienced researchers conducting basic research in a relevant DOD area of interest. This environment provides an excellent opportunity for students to select and complete their thesis requirement.

Four NPS graduates have completed theses in support of the A2C2 project:

Capt. Michael C. Berigan, USMC, *Task Structure and Scenario Design*, Masters Thesis, MS in Systems Technology (C4I Systems), Naval Postgraduate School, Monterey, CA., June 1996 [Berigan, 1996].

LCDR Greg S. Higgins, USN, *The DDD-III: A Research Paradigm for Abstracting Joint C3 Scenarios for Tier-I Experiments*, Masters Thesis, MS in Systems Technology (C4I Systems), Naval Postgraduate School, Monterey, CA., June 1996 [Higgins, 1996].

LT Neil A. Smith, USN, *Performance Measure Analysis of Command and Control Organizational and Task Structures*, Masters Thesis, MS in Operations Research, Naval Postgraduate School, Monterey, CA., June 1996 [Smith, 1996].

LCDR James F. Drake, USN, *Design and Development of the Scenario for the Second NPS A2C2 Experiment*, Masters Thesis, MS in Systems Technology (C4I Systems), Naval Postgraduate School, Monterey, CA., June 1997 [Drake, 1997].

Two additional A2C2 related theses are expected to be completed by the CCRT Conference in June 1998:

Capt. Robert Benson, USMC, *Conduct and Assessment of A2C2 Experiment 3*, Masters Thesis, MS in Systems Technology (C4I Systems), Naval Postgraduate School, Monterey, CA., June 1998 [Benson, 1998].

CPT. Davis Greenwood, USAF, *Adapting the A2C2 Experiment for MTWS*, Masters Thesis, MS in Systems Technology (C4I Systems), Naval Postgraduate School, Monterey, CA., June 1998 [Greenwood, 1998].

Two more theses in support of the A2C2 project are in progress.

Capt. James Kelly, USMC, *Use of MTWS for A2C2 Tier-2 Experiments*, Masters Thesis in partial fulfillment for MS in Systems Technology (C4I Systems), Naval Postgraduate School, Monterey, CA. [Kelly, in progress].

CDR. Stephen M Olechnowicz, USN, *Identification and Evaluation of Organizational Structures and Measures for Analysis of Joint Task Forces*, Masters Thesis in partial fulfillment for MS in Operations Research , Naval Postgraduate School, Monterey, CA. [Olechnowicz, in progress].

4. The Systems Technology Laboratory (STL)

The A2C2 experiments at NPS have been conducted in the Interdisciplinary Academic Center's Systems Technology Laboratory (STL). This facility uses DDD (to be discussed later) during A2C2 trials to present the player teams with the context in which they attempt to perform their missions.

The STL is a state-of-the-art laboratory providing researchers, faculty, and students access to classified and unclassified computing, networks and applications. Some of the capabilities are the Global Command and Control System (GCCS), the Global Broadcast Service (GBS), the SIPRNET (Secret Internet), the DARPA Leading Edge Services Network (LESN), and several models, simulations and wargames. Two of the simulations/wargames that have direct applicability to the A2C2 project and are included in the C4I Systems curriculum are the Distributed Dynamic Decision-making (DDD) III simulator and the Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS).

4.1 DDD

The DDD was developed at the University of Connecticut (UCONN) for human-in-the-loop experimentation. It is a fairly abstract simulation that is easily modified to examine different experimental domains and facilitates custom data collection [Kleinman et al., 1996].

As a result, the DDD has been used to support team decision-making experiments for several years at several locations including NPS. The version of the DDD currently installed in the NPS STL was modified by A2C2 researchers at UCONN, NPS, and APTIMA to facilitate experimentation in the joint C2 domain, which is the focus of the project. Its abstraction and flexibility make it ideal for relatively basic research experiments (called Tier 1 experiments in the A2C2 project).

All of the officer-students who participated in experiment 3 were trained as DDD players. The Lead Team students who had been trained to use DDD the previous year when they were players were responsible this year for training the players on the use of DDD and were trained themselves to manage the data and scenario files, and to develop/modify the scenarios for experiment #3.

4.2 MTWS

MTWS was recently developed by the Marine Corps to support Command Post and Field Exercises. It was acquired and installed in the STL under the co-sponsorship of ONR, the USMC and NPS to support student education and research of which A2C2 is a prime example.

Within the A2C2 project, MTWS is to be used to support experiments requiring a higher degree of operational realism and fidelity (termed Tier 2 experiments) than that provided by the DDD. MTWS provides a more realistic depiction of terrain and unit capabilities as well as stochastic resolution of combat engagements. The level of detail includes weapon system capabilities, detection ranges, weapons effects, and water and ration consumption rates. Weather can also be simulated with corresponding effects on visibility, movement, and air operations.

In the C4I Systems curriculum, MTWS is used to provide hands-on experience with a current, joint wargame. Students are taught how to operate player stations, how to develop and execute scenarios, how to operate the system and how to examine recorded post game results. Of the simulations/wargames examined for procurement it provided the best combination of joint force representation, ease of set-up and use, and ease of training [Porter, 1996]. It also featured well-structured and developed code (ADA). It is anticipated that experimentation and education at NPS using MTWS will provide excellent results.

CPT Greenwood's thesis involves using MTWS to recreate the scenario used by DDD in A2C2 Experiment #3. Playing the scenario in MTWS will permit comparison of results with the DDD results. For example, MTWS attrits forces that are destroyed, DDD penalizes the player for the same action but allows the unit to continue scenario play. This technique reduces noise in the data by ensuring that critical units survive for an entire trial [Greenwood, 1998].

5. Conclusions

A2C2 research at NPS creates a valuable synergy among students, faculty and researchers. Combining education with practical applications in the laboratory and with direct exposure to on going leading edge research by experts contributes to the quality of education provided to the students. The A2C2 project provides a rich ongoing educational and research environment that encourages students to complete their thesis requirements in an area directly related to the A2C2 project. These efforts in the past have enhanced the overall A2C2 research results. The researchers gain by the symbiosis between the researchers' requirements to have operationally experienced subject area experts to conduct credible experiments and the NPS student officers who have these attributes. The NPS faculty associated with the A2C2 experiment, and its supporting classes, also benefit by participating in and observing leading edge, and in this case, relevant national research on an ongoing basis. Finally, DOD and the Services benefit from the enhanced quality of the A2C2 project results due in part to the use of students as players to produce credible results, the use of students as Lead Team members to expose them to the planning and conduct of a major experiment – an experience that will likely prove valuable later in their careers, and because the students' efforts as Lead Team members and student theses results provide value added to the A2C2 project on a no cost basis.

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