# The A2C2 Experimental Concept[1]
# (Tutorial)

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## Abstract

The Office of Naval Research sponsored Adaptive Architectures for Command and Control (A2C2) program is conducting research in joint military command and control decision making and adaptation in joint military command and control architectures. It is a synergistic combination of several kindred research processes involving field research, theory building, model development and human-in-the-loop (HIL) experimentation. The HIL experimentation is central to the program overall. It is synchronized with and supports the other processes, and they, in turn, support the experimentation. Thus, individual experiments are not independent entities. Experimental

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conceptualization and design is based on the current state and needs of each of the processes (including the experimentation), and the experiment is conducted in a manner that provides data to advance the project as a whole and the component processes individually.

Data is required throughout the A2C2 program, for model development, testing and improvement and for theory development and testing. The major vehicle for generating and collecting this data is a series of human-in-the-loop (HIL) experiments. But, the same models that require data from the experiments are also involved in the design of the experiments. Models play key roles in the experiments well before the actual human players are involved. They are used to design C2 architectures to be used in the experiments, to evaluate various characteristics of the architectures, to predict organizational behavior based on these characteristics, and to pre-play (simulate) the experiments to ensure that the investigation focuses on the important points in the design space. It is important to note that these models are intended for other uses besides supporting the experimentation – the experimentation helps make them better models for these purposes. The model use and model validation and improvement needs have to be considered in the experimental concept. Theory development and testing also plays a key role in the experimental design. Besides providing a vehicle for testing theories, the experiments produce results that lead to new or modified theories. These interdependencies and the concurrent use of inductive and deductive methods lead to the unique challenge of conceptualizing and designing HIL experiments as an integrating part of a multi-dimensional research program.

Research questions must be formulated and scenarios developed in such a manner that:

- answering the questions accomplishes the research objectives,
- the questions can be tested empirically,
- the experiment is supportable by models,
- the scenario is supportable by one of the available experimental simulators,
- the scenario can be operationalized at the proper level and domain for the players.

Typically, one overarching research question is defined that requires manipulating the independent variables in a manner that also generates the data necessary to support the modelers and the subsidiary research questions. But, the process is iterative. Considering the needs of all of the research processes, officer-students and faculty at NPS work with other A2C2 researchers to define the operational concept for the experiment. Operational concept is a military term that includes the mission and also the general structure of how the mission will be accomplished - what types of forces, the geographic scenario and the time sequence of objectives. In the experimental world it might be thought of as the strategy of the experiment.

The overarching research question is the basis for establishing the hypotheses for the experiments. Most A2C2 research questions are based on results from previous experiments, either because the findings indicate refinement in theory is necessary or because the results are understood well enough to allow progression to the next level of experimentation. Once the modelers have formulated the organizational hypotheses based on the research question and the relevant context has been established, a specific scenario is selected. The scenario must lend itself to the generation of data that is highly likely to reveal operationally and statistically meaningful results if they in fact

exist (and meet the other research needs discussed above). War is exceedingly complex and the influence of a small number of factors is often submerged in the inherent uncertainty of the situation. The experimental scenario must be designed such that key variables are explicitly identified and can be controlled and scientifically manipulated to test hypotheses and to potentially show effects that have risen above the noise of war.

Modelers then perform the pre-experiment design and analyses discussed above, and experimenters ensure that the scenario can be operationalized in an experimental simulator and devise methods to focus player effort in the areas of interest (e.g., if coordination of assets is important to the research, the scenario must contain several tasks that require the use of multiple assets). Through a series of feedback loops, the scenarios, architectures and possibly models are revised until the stage is set for an effective efficient experiment.

The constraints of time and resources are also critical in establishing the details of the experiment. The experiments at NPS are usually constrained to decision-making processes that can be represented in a small team of low to mid grade officer-students with limited time availability. (The rank constraint does not seem to be severe, however, since the few paired experiments conducted to date with more senior officers have show no significant differences in results.) The use of simplifications in the scenarios and the abstract nature of the simulation allow each player to represent an operational commander and his or her staff and forces in managing assets and to participate in team decision-making with other operational commanders on the team. The strengths and difficulties of this mixing levels of analysis must be considered in the design, as must the information systems required to support play e.g., voice and computer LANs, computer displays of the situation (Common Operational Picture) and other means of communication.

This tutorial discusses the A2C2 experimental conceptualization and design process.