Research on Complex System-of-systems Combat Experiment

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Abstract. This paper expounds the root of complexity of system-of-systems combat, and summarizes the methodology and technical route of complex system-of-systems combat experiment. Then, this paper studies the framework of system countermeasure experiment, and points out the technical difficulties of system countermeasure experiment.

1. Introduction

As a method to study the characteristics and laws of war and military action, combat experiment is of great significance to the formation, mechanism and mode of formation of system combat capability, and also to the construction of system combat capability. The complexity of system of systems operations also requires us to introduce complexity when conducting operational experiments.

2. The Root of Complexity of System-of-systems Combat

The basic form of information war and intelligent war is system-of-systems combat. System-of-systems combat means that under the support of information system, all kinds of combat elements, combat units and combat systems are integrated into an organic whole to jointly perceive the battlefield situation, share the battlefield information in real time, accurately coordinate the battlefield action, carry out the combat task synchronously, and conduct accurate command in time. Finally, the most accurate combat effectiveness is released to the most valuable combat target. In system combat, any combat unit is a component of the system, and there is no isolated combat unit. The level of combat system, and the interaction, integrity, adaptability and emergence of system operations are the root of complexity in system-of-systems combat.

3. The Methodology and Technical Route of Complex System-of-systems Combat Experiment

System combat experiment is to use the principles, methods and technologies of scientific experiments to study the characteristics and laws of war and military operations empirically in a controllable and measurable combat environment, so as to provide scientific basis for military decision-making and war practice.

3.1. Methodology of System-of-systems Combat Experiment Research

At present, there are mainly three kinds of methodology in system of systems combat experiment research. The first is holism. This is a top-down analysis method, that is, the research object is regarded as a system, the system is properly decomposed, at the appropriate level, through the study of the overall goal of the system, to find the way to solve the problem. The key of the whole analysis method is to analyze the problem correctly, determine the level of the problem and find the core of the problem. The second is reductionism. This is a bottom-up method, that is, the research object is modeled from the most detailed entity level as much as possible. Through the independent behavior
and interaction of each entity in the system, the comprehensive effect is finally produced, that is, the emergence of the system. However, how to determine the smallest entity and determine the behavior of the entity in the system, and finally achieve this overall effect, is also a big problem. The third method is the integrated method. This is a comprehensive methodology with multiple methods. In the study of complex system, this method may be a method that can completely adapt to all kinds of complex situations in war. However, the key to the success of this method is how to integrate all kinds of methods effectively.

3.2. Technical Route and Thinking

The mainly technical route and thinking are complex network theory, complex adaptive system and agent-based modeling and simulation technology, system dynamics, system level and fractal theory and Self organization theory.

4. Framework and Technical Difficulties of System Countermeasure Experiment

4.1. Experimental Framework of System Antagonism

The flow of system countermeasure experiment is shown in Figure 1:

- **Problem description**
  - Conceptual modeling of military problems
  - Hypotetical condition
  - Military rules
  - Independent variable
  - Dependent variable

- **Experimental design**
  - Experimental design
  - Experiment design
  - Experimental design
  - Scenario design

- **Experimental implementation**
  - Simulation experiment
  - Practial drill
  - Actual combat

- **Experimental evaluation**
  - Data mining
  - Correlation
  - Causal analysis

**Figure 1.** The flow of system-of-systems combat experiment

In order to explore and understand the complex issues involved in system-of-systems operations, the experimental activities should be composed of a series of activities such as preparation, implementation, analysis and synthesis. Experiments must be carefully designed and analyzed in order to achieve results.

4.1.1. Experiment Preparation Stage. The main work in the experiment preparation stage includes the abstract of experiment objective, the design of objective function, the selection of index analysis, the selection of experiment mode (simulation, real soldier), the selection of model granularity and scenario design. Before the experiment, we should make clear the research problems and the main points to be concerned. At present, computer simulation is the key method in the system-of-systems combat experiment. In fact, because of the controllability, repeatability and low cost of computer simulation, it has become the main means of system-of-systems combat experiment. The system-of-systems combat experiments mostly use the simulation platform based on multi-agent technology.

4.1.2. Experiment Implementation Stage. The experiment should carry out according to the experiment plan. In the implementation, we should pay attention to several points: Firstly, we must carry out
targeted training for the personnel participating in the experiment. People who are not familiar with the experiment may have wrong results. Secondly, we should pay attention to the collection and arrangement of experimental data in the process of experimental implementation. In the process of data collection, we must ensure the quality and integrity of data.

4.1.3. Experimental Evaluation Stage. The purpose of experimental evaluation and analysis is to synthesize and mine the data of experimental results by various analysis methods, and to intuitively express the analysis results by visual means, so as to find out the rules or abnormal points of experimental problems and assist the experimenters to make conclusions. In the data analysis after the experiment, it is emphasized to apply the theories of various complex systems to the result evaluation and analysis, and to combine the micro interpretation of computer simulation data to find out the rules.

4.2. Technical Difficulties

4.2.1. Construction of combat experiment platform. As a kind of complex system, the system-of-systems has inherent ‘uncertainty’ characteristics. It is impossible for us to establish an accurate experimental environment, and we can only continuously improve and develop it. The experimental platform is the basis of system antagonism experiment. From the development of complex system simulation, at present, the simulation platform of complex system is basically based on agent technology. More mature simulation platforms include Swarm, EINStein, Repast, AnyLogic platform, etc. These platforms generally abstract the basic combat unit as an individual with multiple adaptive characteristics (agent), as the basic elements of the system, and describe its behavior mode and tactical details, and then simulate the whole combat process layer by layer. Generally, these platforms are general platforms. When conducting system-of-systems combat experiments, it is necessary to build relevant models according to the characteristics of system of systems operations. At present, how to continuously improve and develop the experimental platform that can meet our own actual needs is a problem we must focus on.

4.2.2. Intelligent modeling. The modeling of decision-making, situation judgment, command, knowledge, experience and emotion in complex system-of-systems combat experiment needs the support of intelligent modeling technology. From the current development of modeling technology, these theory and technology are still in the initial stage, and are far from being able to solve the practical problems of complex confrontation.

4.2.3. Complexity description. In the system-of-systems combat, complexity has become a basic problem that we must consider. Ignoring complexity and according to traditional methods, we can't reveal the laws and characteristics of modern war. But so far, complexity science is still an incomplete development. Although there has been some progress, there is no good way to describe complexity. How to describe the complex phenomena in the system-of-systems combat scientifically is the key to the experiment.

4.2.4. Complex system modeling. It is difficult to describe such a complex system with a single modeling method because it involves many dimensions, a large span of time and space levels, a large number of basic units, a large degree of correlation, uncertainty and diversity. From the current research status of complex system modeling, the commonly used methods are neural network modeling, fuzzy logic modeling, rough set theory modeling, fuzzy neural network modeling, fuzzy model and neural network combination modeling, genetic algorithm and neural network combination modeling, shape based modeling, multi model method modeling, structure modeling, agent-based technology modeling. These methods generally describe one aspect of complex system, but they are not mature methods of complex system modeling. Under the guidance of scientific methodology, it is still a technical difficulty to establish a perfect modeling theory and method of complex system.
4.2.5. Construction of Virtual Battlefield Environment. Virtual battlefield environment is the carrier of experiment, so the construction of virtual battlefield environment is the basic problem that experiment must solve. For complex systems, there are interactions of information, material and energy between entities and operational environment, which is one of the basic sources of complexity. The entity influences the environment, which in turn affects the behavior, structure and quality of the entity. Virtual battlefield environment is an important factor that affects the reliability of experiment. At present, the problems of dynamic terrain, special effects, access and management of massive data are still the difficulties of constructing virtual battlefield environment.

4.2.6. The VV & A of operational experiment. The reliability and validity of the experiment affect the correctness of the experiment results. The VV & A of the experiment includes the model, data and VV & A of the experiment process. At present, the importance of VV & A in combat experiment has been paid more attention by users and developers, and it has become the key basic technology of combat experiment. The theory and method of VV & A have been established and applied. However, the organization, process, theory and method, practice and system of war experiment VV & A are not perfect, so we need to study and deepen it from theory and practice.

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