A Cooperative Command and Control Model

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***Abstract*—Command and control (abbreviated C2) is the key of integrated cooperative engagement, and directly decides the process and outcome of war. As the background of integrated engagement, in view of the analysis of several typical C2 models, based on synergetic theory and method, the definition of cooperative C2 was elaborated, and a kind of cooperative C2 model was proposed. Then, framework of the model was given, the composition and function of the model were described, and the logical structure and characteristics of the model were analyzed. This research provides a new study idea and method for C2, and it has important reference value for the design of future C2 system.**

Keywords- cooperative engagement; command and control; model; cooperation

I. INTRODUCTION

Since the 21st century, integrated cooperative engagement has become a typical combat form of information age, and the research on integrated cooperative engagement has drawn increasing attention [1]. Cooperative engagement [2, 3] generally refers to different forces in different fields around a common goal fighting together. In the integrated cooperative engagement, both depth and breadth of arms coordination are far beyond cooperative engagement in the traditional sense. Integration may be deemed to cooperative engagement in informationization war, which integrates different units into an whole. Under unified C2 by cooperative engagement command organization, the whole operation below campaign scale is implemented by the integrated C4KISR system.

C2 is at the heart of cooperative engagement, which is the key of information advantage eventually into competitive advantage, plays the roles of nexus, organization and coordination. Relevant institutions at home and abroad attaches considerable attention to model research on C2 of integrated cooperative engagement [4-6], but which is basically qualitative theory, the lack of simple, intuitive model, and not convenient for system analysis and objective assessment. In this paper, combining with the characteristics of cooperative engagement and the analysis of classical C2 models, based on synergetic theory and method, a cooperative C2 model is designed, and which‘s structure and function are researched to lay the foundation for the next cooperative C2 method and technical research.

II. CONCEPT DESCRIPTION OF COOPERATIVE COMMAND AND CONTROL

According to “The military Language of the PLA”, C2 [3] means commanders and their units to control and restrict the operations or activities of troops. Essentially, cooperative C2 is also a kind of C2, but more emphasis on coordination and consistency of various activities in C2. For maritime fleet in cooperation, cooperative C2 refers to sensors, weapons, commanding system equipment, and fire control equipment on each combat platform of the formation are connected via data link, and flexible combination for information sharing. So that the equipment distributed in various combat platforms are combined into a whole to complete the submarine, sea, air and missile defense and other missions.

Therefore, cooperative C2 under integrated cooperative engagement is more highlighted by network technology that all combat units in combat zone can form an whole, which emphasizes information sharing between combat units within the combat zone. Consequently, the cognitive level of commanders reaches a common understanding, increasing the consistency of decision cognition, to significantly improve the overall combat effectiveness and flexible adaptability.

III. TYPICAL COMMAND AND CONTROL MODELS

C2 model is a description of the C2 process, but due to its complexity and nonlinear, many models only highlight certain attributes of C2, and it is hard to break.

A. Command and control in the industrial age

In the industrial era, the description of C2 is based on cybernetics, and the two sides scrabble for the battlefield, forming the whole confrontation of system. Correspondingly, there are several typical interpretation models to describe the C2 process [7, 8]: cybernetic interpretation model, epistemological interpretation model, OODA loop model. The first model primarily lacks enough description of human role, so limited in application. The second model gives prominence to the interpretation of cognitive activity in the C2 process, but the features of the process reflect inadequately. The observation, orientation, decision and action model (referred to as OODA) overcomes the shortcomings of above models, which has been widely used,

and it is more effective to explaining the enemy interactions in the C2 warfare.

B. *Command and control in the information age*

After entering the information age, the U.S. military believes that the concept of C2 in the industrial age has not been applicable to cooperative engagement for the allied forces, especially not for complex military operations in the 21st century [9]. The U.S. military advocates using "command and coordination" to replace "command and control" in future operations. In the complex battlefield environment, through consultation and collaboration they obtain consistent intentions and acting, and finally reach the effect of convergence.

Therefore, the U.S. military believes that the information age of the 21st century should be emphasized on the agility of C2, and proposed NATO Network Centric Warfare Command and Control Maturity Model (N2C2M2) with NATO experts. This model provides a method, space and frame of C2: you should select the C2 approach in different maturity level based on the nature and characteristics of the task. Meanwhile, the maturity model shows that any kind of C2 method includes both benefits and costs, and there is no omnipotent method to solve all problems. The higher maturity level implies that it needs more information exchange and more energy resources consumption, instead of blindly pursuing a high level of C2 method.

IV. COOPERATIVE COMMAND AND CONTROL MODEL

A. *Framework of the cooperative command and control model*

To adapt to the self-adaptation and self-synchronization requirements for C2 under informationization, based on synergetic theory and methods, on the basis of the existing C2 model, this paper introduces cooperation unit, establishes cooperative mechanism of information mining, active perception and integration of combat collaboration, and tries to build a new C2 model, namely cooperative C2 model, referred to as C2+C model (Command and Control + Cooperation), shown in Figure 1. In C2+C model, the cooperative goal eventually occurs in the cognitive domain, and the cooperative mechanism is formed in the information domain and cognitive domains, reached in the cognitive domain, and implemented in the physical domain. The model covers the following functional modules.

1) Information collection: Based on the sensor reports provided by various combat platforms, this module detects the status of target and objects in the combat environment in real time. Those detected data is the main source of information fusion, which and other data sources together constitute the data input of information fusion system.

2) Information fusion: This module processes the detection information of sensor systems by fusion for obtaining state estimation and target properties, which provides an important basis for the subsequent processes such as information mining, plan identification, and active perception.

3) Information mining: In use of information mining technology, this module synthetically analyses, reasons, extracts and mines the information flow of C2 systems, and expresses the combat information meeting for commanders' needs from the implicit and unknown message in environment.

4) Plan recognition: According to the observed fragment and trivial phenomenon, this module concludes a reasonable causality, complete and comprehensive plan description, and digs deeper the implied enemy battle plan and attempt in combat evolution which is non-appearance in battle space.

5) Decision making: According to the result of situation assessment and based on tactics rules, this module produces combat programing, generates operational decision and operations, maintaining tracking of operations in combat, inspecting decision effect in real time, and makes decision in time along with the situation changes.

6) Cooperation unit: This module completes the cooperation of C2, and generates cooperation plan and cooperation program in view of situation awareness, command decision, arms control, and such tasks, which is divided into two layers: planning coordination layer and task scheduling layer.

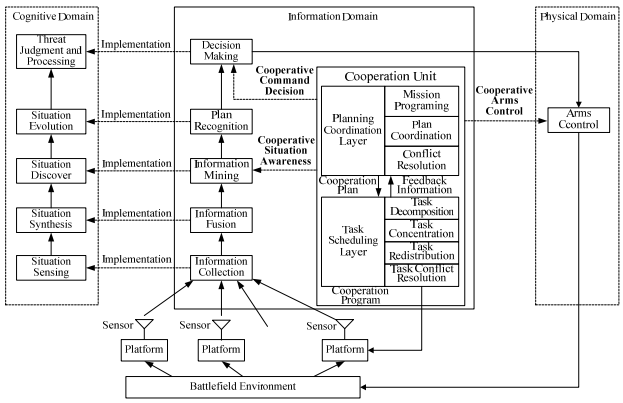

Figure 1. A cooperative command and control model (C2+C model).

B. *Logical structure analysis of cooperative command and control model*

1) Logical structure of C2+C model: Cooperation of C2+C model is mainly to solve situation awareness, command decision, arms control and other issues, organized and fulfilled by the cooperation unit. Cooperation unit is divided into planning coordination layer and task scheduling layer to accomplish their task at different levels, which respectively generates cooperation plan and cooperation program, and the cooperative objects include manned and unmanned platforms. Based on information sharing, the model achieves the global optimum and dynamic optimization of resources allocation by making multi-platform cooperative situation awareness, command

decision and arms control, in order to make the best working way of each platform to maximize the overall combat effectiveness of multiple combat platforms.

The cooperative process of C2 is a reactive programming cycle. The commanders carry out mission programming and plan establishment in accordance to the task to be achieved. Then, the commanders at all levels according to this plan launch military actions, and the results of actions lead to the evolution of the battlefield situation. On the other hand, the situation change further through the battlefield apperception gives feedback to the commanders, and through the collection and processing of information, the multidimensional performance and generation of situation, sharing and interaction of operational view provides understanding of the current situation for the commanders. Then, the commanders according to the comprehensive judgment of information identify the enemy intent or plans, and estimate the threat of enemy plans, based on the threats adjust or amend our operational programing (namely "reactive programing"), and so. It ultimately reflects a complete C2 process.

2) Logical structure of cooperation unit in C2+C model: The cooperation unit in the model is divided into two layers from top to down: planning coordination layer and task scheduling layer, which respectively reside in the command center and each combat platform. Planning coordination layer disassembles the whole mission (air defense, anti-submarine warfare and anti-ship warfare, etc.) into work targets of each combat platform and achieves operational cooperation between the platforms, and achieves mission programing and task coordination through a predetermined protocol in mutual consultation for making combat system to form a whole. Task scheduling layer is to realize internal coordination of operational platforms, which is composed of various programing algorithm and management software, and to achieve task decomposition, task management, task conflict resolution and so on for operational platforms, which also provides negotiation information with other operational platforms for planning coordination layer.

As shown in Figure 1, through the reciprocating transmission each layer realizes information sharing. It is the more close to low-level modules farther down, while higher up the information content and decision have more global significance, and the time scale of decision also becomes longer. Due to information sharing, in fact each level has considerable "global conception" and relatively when necessary develops appropriate reasoning and decision algorithms to improve collaboration level and autonomy degree of the system .

a) Cooperation of multiple combat platforms: Cooperation of multiple combat platforms is more complex than that of single combat platform, which involves more optimization index and control variables. It needs both by the mission programing to solve the problem which platform performs which or what task, also to solve mutual influence of plans and actions among combat platforms through plan and coordination during the execution of tasks, shown in Figure 2. For the complexity of the Cooperation problem among multiple combat platforms, at the same time using a distributed control architecture, based on the idea of hierarchical control, cooperative function of multiple combat platforms is lengthways divided into three levels, at different levels using different models and methods to solve, and the function of all levels is completed in planning coordination layer.

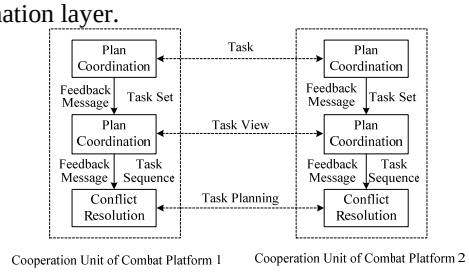

Figure 2. Hierarchical logical structure of Cooperation of multiple combat platforms.

- Plan coordination. Various combat platforms achieve one another's dynamic allocation and adjustment of task through consultation, program action steps to complete the task, and form task planning in the task sequence.
- Plan coordination. Various combat platforms detect one another's constraint relation of tasks by exchanging task view, consult with the combat platform implementing relevant tasks, and in accordance with the results adjust task scheduler and achieve tactical coordination.
- Conflict resolution. Various combat platforms achieve one another's conflict abatement of task planning through consultation, and merge individual task planning into cooperative mission planning.

b) Internal cooperation of single combat platform: For each combat platform, the logical framework of its internal cooperation includes four levels such as task decomposition, task concentration, task redistribution and task conflict resolution, shown in Figure 3. The internal cooperation of combat platform is achieved by the task scheduling layer.

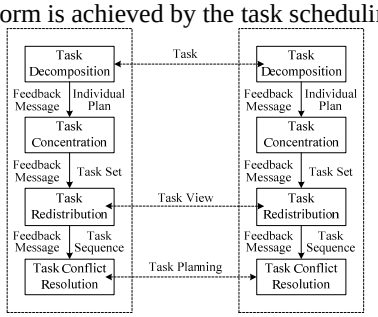

Figure 3. Hierarchical logical structure of internal cooperation of single combat platform

- Task decomposition. Combat platforms according to the received cooperation plan decompose their own

platform tasks, and can be subdivided into executable subtasks.

- Task concentration. According to the subtask sequence from task decomposition, it decides the order of executing subtasks and generates the optimal execution plan of subtasks.
- Task redistribution. In accordance with the execution plan of subtasks, it generates the specific implementation steps to complete subtasks, and solves the problem of how to implement the subtasks.
- Task conflict resolution. While coming forth conflict such as resources competition, command intervention, and so on among subtasks, it executes task conflict resolution.

Above all levels first carry out control in the coarser granularity space, and then control in the finer granularity space again. The results are given by top-down and the feedback is transferred by bottom-up. It is interrelated and influencing to each other between levels, which is an integrated cooperative control process.

V. CONCLUSIONS

Due to the complexity and nonlinearity of the C2 process in the information age, it is difficult to build a suitable C2 model in order to achieve optimization and high efficiency of troops. Based on the self-adaptation and self-synchronization needs of C2 in the information age, this paper establishes cooperative mechanisms on information mining, initiative perception and integration of combat cooperation, and constructs a cooperative C2 model, referred to as C2+C model, in order to achieve an efficient, flexible and fluent C2. The model has many characteristics such as scalability and hierarchy, which can provide a new research idea and method for cooperative C2, and has a certain reference value to enhance our naval cooperative engagement capability. The follow-up work is modeling and implementation of this model so as to further verify the validity of the model.

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