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Process Modeling and Simulation Optimization of Reconnaissance Satellite Information application chain Architecture

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Abstract. Aiming at modeling and simulation optimization of information application chain architecture, a structural modeling method and an iterative simulation optimization method are proposed respectively based on DoDAF (department of defense architect framework) based on importance degree. This paper first defines the composition structure of reconnaissance satellite information application chain and constructs its task structure model. Secondly, it proposes the modeling and simulation optimization method of reconnaissance satellite information application chain architecture. Thirdly, The static structure model and the simulation structure model are constructed by that method. Finally, based on the simulation analysis of the system structure simulation software, the resource importance spectrum affecting the information chain performance of the reconnaissance satellite is obtained, and the reconnaissance satellite information application chain is optimized and verified by the stepwise iteration method. The effectiveness of modeling and simulation optimization methods are tested.

Introduction

Reconnaissance satellite information application chain is the network structure which provides the reconnaissance surveillance information to the combat users in the course of war. It plays an important role in the target reconnaissance and strike assessment [1]. At present, the research on reconnaissance satellites in combat is mainly at the stratagem of strategy and campaign, and less on tactical level. The research on reconnaissance satellite system and the application of combat system is more, and less on the whole application process [2][3].The purpose of this paper is to consider the applications of reconnaissance satellite information from the perspective of the whole process and multiple levels, and to promote the tactical application transformation of reconnaissance satellite. It will promote the overall optimization of the reconnaissance satellites information application chain [4].

Based on the information chain composition structure and task structure model, this paper proposes a structural modeling method and a simulation optimization method. The model of the reconnaissance satellites information application chain is constructed based on the DoDAF theory [6][7][8] and the activity-based modeling[9][10]. Based on the simulation optimization method, the reconnaissance satellite information chain is analyzed by means of SA (System Architect) software [11][12]. These results have high value and significance for understanding the structure of reconnaissance satellite information application chain, studying its application flow and exploring its application.

Composition Structure and Structural Model of Reconnaissance Satellite Information Application Chain

It can been seen that reconnaissance satellite information application chain nodes contain the combat user node and reconnaissance satellite system node from the definition of reconnaissance satellite information application chain , as shown in Figure 1. The nodes of the reconnaissance satellite information application chain are made up of information acquisition nodes, information relay nodes, information receiving nodes, information processing nodes, information application nodes, integrated task control center, ground monitoring center, ground station management center

and relay satellite control center. Information receiving nodes are mainly composed of imaging reconnaissance satellites and electronic reconnaissance satellites. The information relay nodes are mainly composed of relay satellites. The information receiving nodes are mainly composed of several ground receiving stations. The information processing nodes are mainly composed of information processing center nodes, The information application nodes are mainly composed of various types of combat users.

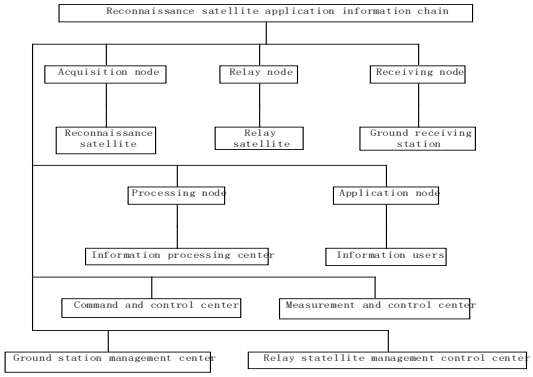

Fig. 1. Composition structure of reconnaissance satellite information application chain

According to combat missions supported by reconnaissance satellites, the combat tasks of reconnaissance satellites information application chain contain four task types as follows: the surveillance task, the reconnaissance task, the evaluation task, and the situation task. In general, the completion of these tasks are completed by the integrated command and control activities, resource scheduling activities, information access activities, information relay activities, information receiving activities, information processing activities and information application activities. And these activities are supported by the reconnaissance satellite information application chain, whose performance level is determined by its structure and the capabilities of its nodes, which ultimately affect the combat mission, as shown in Figure. 2.

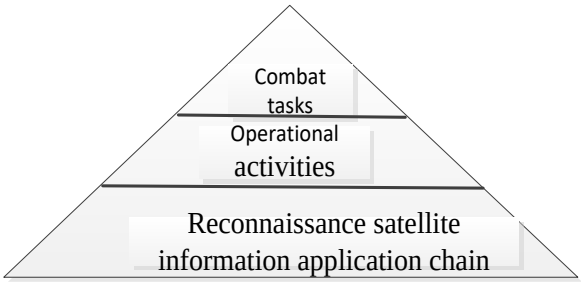

Fig. 2. Structural model of reconnaissance satellite information application chain

Modeling and Optimization Methods of Reconnaissance Satellite Information Application Chain

From the system point of view, reconnaissance satellite information application chain is composed of the user system and reconnaissance satellite system complex systems and has the complex system structure characteristics, so the theory and method of structure design can be applied in the design of reconnaissance satellite information application chain.

DoDAF (department of defense architect framework) provides a standardized description framework for describing architecture, and provides a guide for architecture design or development. DoDAF designs view products in three main ways: all-views (AV), operational view (OV), system view(SV), and technical standard view (TV). This paper mainly studies the design of information chain architecture of reconnaissance satellites from the view of operational view.

DoDAF provides a description of the product specification, but did not provide a specific design and implementation methods. Therefore, it is necessary to introduce other modeling methods and tools to design its structure. At present, there are three main methods of system modeling: structural modeling method, object-oriented modeling method and activity-based modeling method, and these methods have their own advantages and disadvantages. In contrast, the activity-based modeling

method is more suitable than for the other two methods in this paper.

SA (System Architect) software is a comprehensive modeling tool with a variety of functions such as business process modeling, data modeling, object modeling and business process simulation and other functions in the defense, military, aerospace, etc. In this paper, we build the reconnaissance satellite information application chain architecture model based on the activity-based modeling method and the SA software.

Through the simulation of SA software, we can obtain some relevant indexes such as the utilization rates of information chain resource and the utilization rates of reconnaissance satellite activities. To some extent, these indexes reflect the influence of activities and resources on the performance of the reconnaissance satellite information application chain. Thus, the activities or resources importance degrees can be defined as their utilization rates. The importance of all activities and resources can be analyzed and ultimately constitutes the importance spectrum. According to the importance spectrum, corresponding reconnaissance satellite information application chain optimization strategy is adopted, and the design is varied with the resource and structure changed. And the purpose of optimization is achieved step by step.

Figure 3 presents an overview of the chain design process based on the importance of resources . The method uses an iterative process to achieve design goals. Based on the needs of different tasks, decision-makers can find some practical and effective improvements through the two-step iterative method .

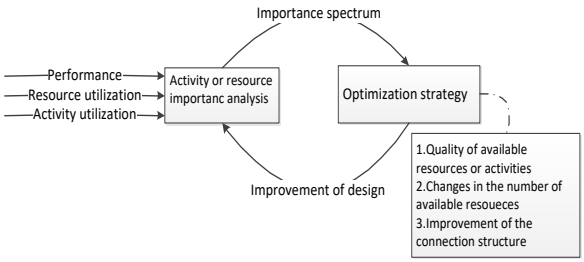

Fig. 3. Satellite information application chain design method based on the importance of resources

An Example

In this section, an example is given to illustrate how to apply the above modeling and optimization methods, and to verify its adaptability and effectiveness.

1) Reconnaissance satellite information application chain active node tree model OV-5

The active node tree model OV-5 is used to indicate the operational activities, the relationships between operational activities, and the output or input streams of activities required to achieve the operational mission. The reconnaissance satellite information application chain operational node tree model is shown as in Figure 4. As can be seen from Figure 4, information chain activities contains measurement and control activities, information acquisition and reception activities. Measurement & control activities and information acquisition &reception activities can be further broken down into smaller activities.

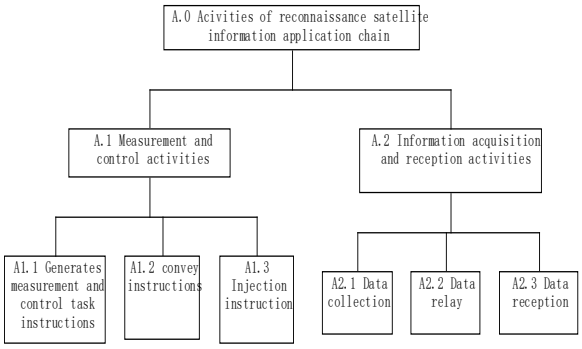

Fig. 4. Reconnaissance satellite information application chain node tree model OV-5

2) Reconnaissance satellite information application chain operational rule model OV-6a

Based on the static model of OV-5, operational rule model OV-6a is constructed by the logical model of time model and resource model. Through the statistics of operating results, the structure weakness and bottlenecks can be discovered so as to provide guidance for structural optimization.

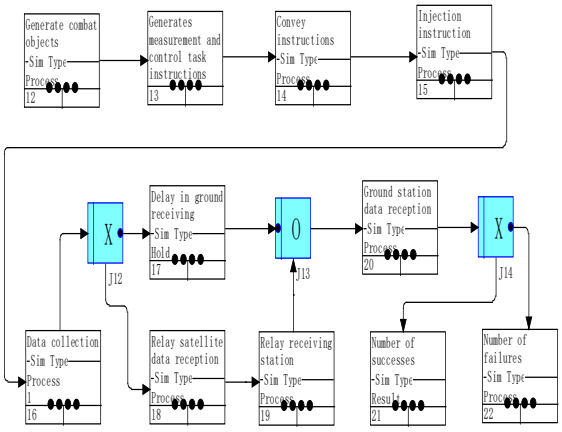

Fig. 5. Reconnaissance satellite information application chain partial combat rule model OV-6a

3) Simulation optimization of reconnaissance satellite information application chain

SA Simulator can simulate the process structure of OV-6a and an information chain operation rule model for reconnaissance satellites. In the simulation, the information chain operation rule model OV-6a is assigned correspondingly resources (system or personnel). By comparing the simulation results of different resource allocation methods, the optimized information chain structure can be obtained gradually.

Step1. OV-6a model simulation parameter setting

a) simulation object parameter settings. In the OV-6a model, the arrival probability of simulation object is considered as the occurrence of a combat target.

b) time model and resource model parameter settings. In the simulation process, the resources are assumed to be in working condition, the shift time is 24 hours a day. Resource execution time is not fixed, but subject to a certain type of probability distribution. Here we assume that the parameter distribution of the resource is shown in Table 1.

Tab. 1. Reconnaissance satellite information application chain time model and resource model parameters

Stage activities	**stage sub-activities**	**Operational resources**	**Resource Allocation (Availability)**	execution time
Measurement and control activities	Generates measurement and control task instructions	Mission planners	3(4)	Normal(25,3)
	Convey instructions	Commanders	3(3)	Normal(20,4)
	Injection instruction	Operators	3(5)	Normal(35,6)
Information acquisition and reception activities	Data collection	Reconnaissance satellites	3(5)	Normal(56,8)
	Data relay	Relay satellite	3(3)	Normal(50,4)
	Data reception	Ground receiving stations	4(6)	Normal(60,4)
		Relay receiving stations	3(3)	Normal(50,4)

Step2. Resource importance spectrum analysis based on simulation

In this section, based on the importance of the reconnaissance satellite information application chain with the actual situation and simulation needs to determine the operational rules and processes of analysis are marked: active idle state (usage), resource usage, .

a) Reconnaissance satellite information application chain performance and resource utilization analysis

The resource utilization rate indicates the relationship between the time at work and the idle time of the resource, and is usually expressed as a percentage of the time spent. Reconnaissance satellite information application chain performance can be described by the time scale. Through the simulation, the resource utilization of reconnaissance satellite information chain can be obtained as

shown in Figure 7. It can be seen that the commanders in measurement and control center and the mission planners in control station are in the top two in terms of resource utilization.

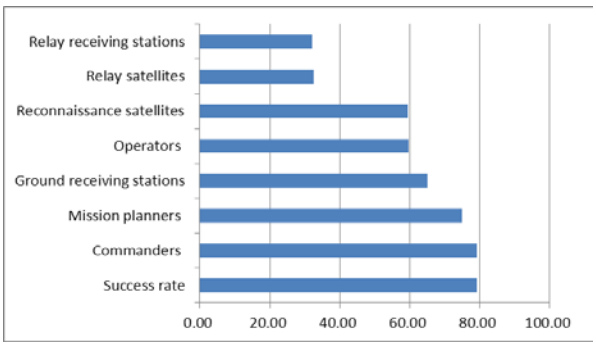

Fig.7. Resource utilization

b) Resource importance spectrum of reconnaissance satellite information application chain

From Fig.7, it can be obtained that the importance spectrum of the information chain of reconnaissance satellites is:

relay receiving stations<relay satellites<reconnaissance satellites<operators<ground receiving stations< mission planners< commanders.

Step3. Gradual optimization of reconnaissance satellite information application chain based on resource importance spectrum

From Step2, it can be seen that the commander's utilization is ranked first, so the information chain performance can be optimized by the improvement commander ability. Figure 8 is the resource utilization and success rate achieved by the improvement of commander's capabilities.

From figure 8, it can be seen that mission planners utilization is ranked first. Similarly, the improvement mission planners ability can enhance the performance of reconnaissance satellite information application chain, as shown in Figure 9. Therefore information chain performance will be improved gradually by the continuous improvement of resource capacity.

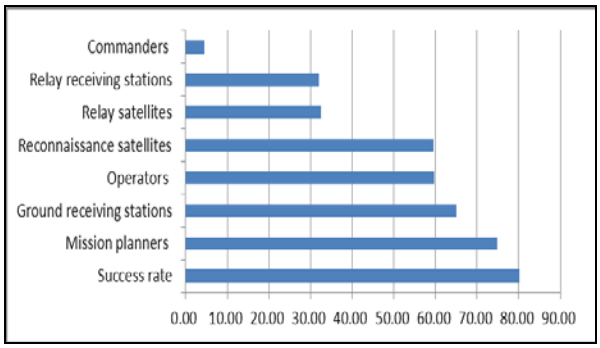

Fig. 8. Optimization based on commanders' ability

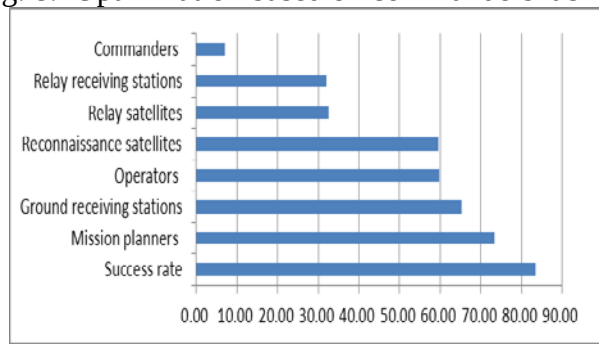

Fig. 9. Optimization based on mission planners' ability

Conclusion

This paper analyzed the composition of reconnaissance satellite information application chain and established the structure model. The modeling method and the optimization method are proposed respectively based on DoDAF and the importance spectrum of resource or activity. And the validity and correctness of above methods are verified by an example. These results are of great significance and reference value for the top-level design, evaluation, optimization and engineering realization of the reconnaissance satellite information application chain. At the same time, the proposed methods are helpful to the modeling and optimization of other systems

References

[1] C.Y.Wang, H.G.Chen, "Space-based reconnaissance and surveillance system development and military application," Sichuan Journal of Armament, vol. 11,2011, pp. 140–143.

[2] P.L. Jiang, "From space-based strategic reconnaissance to the development of space-based tactical reconnaissance," Aerospace Electronic Warfare, vol. 6,2014, pp. 17-20 +29.

[3] D. G. Qin, L. Y. Chen, "Space-based Information Acquisition System Integrated Command and Control," Journal of Equipment Academy, vol. 1,2016, pp. 63-68.

[4] G. Liu,L.M.Li,D.S.Qiu,F.F.Tang,"Study on Design Method of Satellite Information Application Chain with Information Center Flow," Journal of Equipment Academy, vol. 3,2014, pp. 63-66.

[5] G. Liu, D.S.Qiu, Z.M.Li,"Application chain chain of satellite information processing capacity assessment method," Systems Engineering and Electronics, vol. 2,2014, pp. 288-292.

[6] DoD Architecture Framework Working Group. DoD Architecture Framework Version 1.0 [S]. Washingtong, U.S: Department of Defense, 2003.

[7] DoD Architecture Framework Working Group. DoD Architecture Framework Version 2.0 [S]. Washingtong, U.S: Department of Defense, 2009.

[8] G.Jian,P.Zou,W.Xiong,"Study on Architecture Model of Space-based Early Warning System Based on DoDAF," Modern Defense Technology, vol. 4,2014, pp. 46-54.

[9] Steven J Ring, Dave Nicholson, Jim Thilenius, et al. An Activity-Based Methodology for development and analysis of Intergrated DoD Architectures [C] // 2004 Command and Control Research and Technology Symposium. Washington, 2004: 1-14 .

[10] P. JIN, W.Xiong, "Research on C4ISR architecture modeling method based on activity," Journal of Equipment Academy, , vol. 5,2009, pp. 50-55.

[11] P. JIN, P.Zou, W.Xiong, Application of Architecture Process Simulation Method in Anti-missile Early Warning Analysis , Journal of Military Research and Systems Engineering, vol. 4, 2010, pp. 35-40.

[12] X. Pan, B.S.Yin, X.H.Wen, "Task Modeling and Simulation of Equipment System Based on DoDAF," Systems Engineering and Electronics,vol.9,2001, pp. 1846-1851.