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A New Service-Oriented Architecture Design Method for Avionics SoS

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Abstract

Firstly, aiming at the research status of single-platform avionics system architecture modeling, using the methodology of US Department of Defense Architecture Framework(DoDAF)2.0, the service view is exploratorily applied to multi-platform avionics system, and the architecture is developed from a service-oriented perspective to realize the transformation of avionics architecture from product-centric to data-centric, in order to meet the needs of multi-platform avionics system in complex information environment. Then introduce the service-oriented multi-platform avionics system architecture modeling process and core key technologies in detail. At last, through the case of unmanned cluster cooperative detection, the modeling process and results of multi-platform avionics system service architecture are introduced.

Keywords: multi-platform avionics; service architecture; DoDAF

1. Introduction

With the development of informationization and networking , the future battle will inevitably be the confrontation between SoS (System of System) and SoS under complex environment. Traditional architecture design method for single platform avionics system cannot break through the barrier of real-time cooperative operation between platforms, and cannot meet the requirements of complex system operation. At the same time, the traditional design method of avionics system architecture takes combat resources as the center and binds tasks and resources tightly, which limits the flexibility of resource utilization and cannot adapt to the battlefield environment of real-time dynamic changes. Therefore, a new form of multi-platform avionics architecture design for system-based warfare in complex dynamic battlefield environment emerges at the historic moment.

Architecture is an abstraction of complex system. It provides a mechanism to understand and manage complex system by defining the composition structure and interaction relationship of the system on the top level, hiding the local detail information of system components[1].At present, the architecture standard models adopted in the military field mainly include Zachman[2] general information system architecture framework, US C4ISR[3] architecture framework, US DoDAF[4] architecture framework and British MoDAF[5] architecture framework.Among them, DoDAF is the most widely studied and applied. The framework has experienced version replacement from 1.0, 1.5 to 2.0, and its architecture development idea has changed from product centered to data centered[4].

Aiming at the design and development of integrated electronic information system architecture, China has preliminarily established electronic information system architecture framework 1.0.The framework includes overall view, operation view, system view and technical view, with a total of 26 products. The architecture modeling research centered on operation view and system view is carried out for avionics system.The above studies are similar to dodaf1.5. They are task-oriented and closely coupled with resources. They can not realize the interconnection, interoperability and other characteristics of multi platform avionics system in the system environment.

Therefore, based on the service-oriented development idea, according to the dodaf2.0 service perspective design method, and according to the design requirements of multi platform avionics architecture, this paper studies the service-oriented multi platform avionics architecture service architecture modeling, so as to lay a theoretical foundation for the future avionics architecture design.

2. Introduction to Modeling Idea and Model of Avionics System Service Architecture

2.1 Proposal of Modeling Idea of Avionics System Service Architecture

The traditional single platform avionics system architecture design idea adopts dodaf1.5 framework and is divided into "operation view, system view and technical view". The operation view describes the tasks and applications of the operation concept, the system view describes the system design of specific resources, and the technical view describes the technical constraints and standards in the task operation. The operation view and system view are bound and associated. Based on the task activities in the operation view, the composition and function of system resources are designed, and the task activities are closely coupled with specific resources. As shown in Figure 1, task activities need system, system function support and information exchange, and data exchange support between underlying systems. From a fundamental point of view, it can provide a service-oriented resource integration mechanism to effectively solve the problem of "interconnection, interworking and interoperability" between system resources under certain mission requirements.

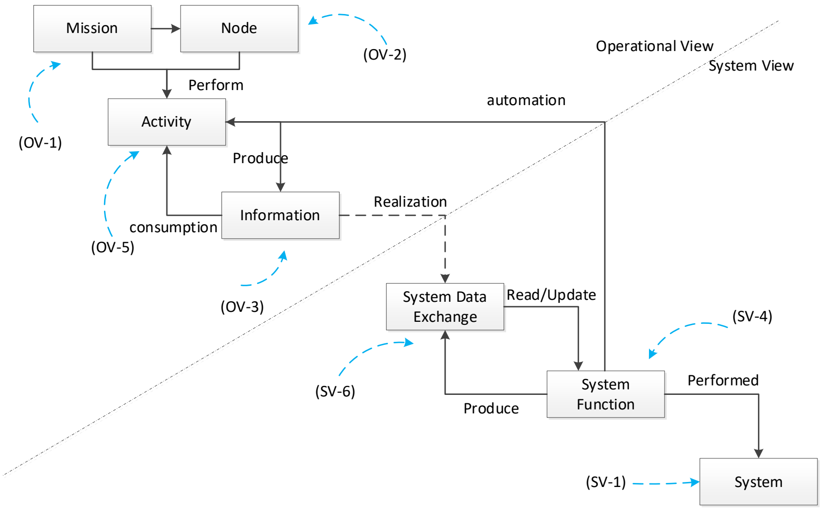

Figure 1 –Relationships among Views in DoDAF1.5

The modeling idea of avionics system service architecture puts forward a possible solution. By encapsulating the resource functions into services, the loose coupling characteristics of services can be used to shield the differences between different developers, different platforms and technical implementations, which can effectively reduce the difficulty of system resource integration. At the same time, the interaction process between services can be adjusted to adapt to the change of task activity process in the operation view; Through the dynamic nature of services, as long as the alternative services can provide consistent interfaces and functions, the problems of dynamic joining and exiting caused by system resources failure can be effectively solved.

Establish a service view description between the operation view and the system view, describe the service definition, service management and the interaction process between services from a service-oriented perspective, and analyze how the service view dynamically integrates system resources under dynamic task changes, which can solve the separation between the activity process logic in the operation view and the implementation of specific system resources in the system view, Improve the reliability and adaptability of architecture design and its corresponding system in the future architecture environment. The service view idea is shown in Figure 2.

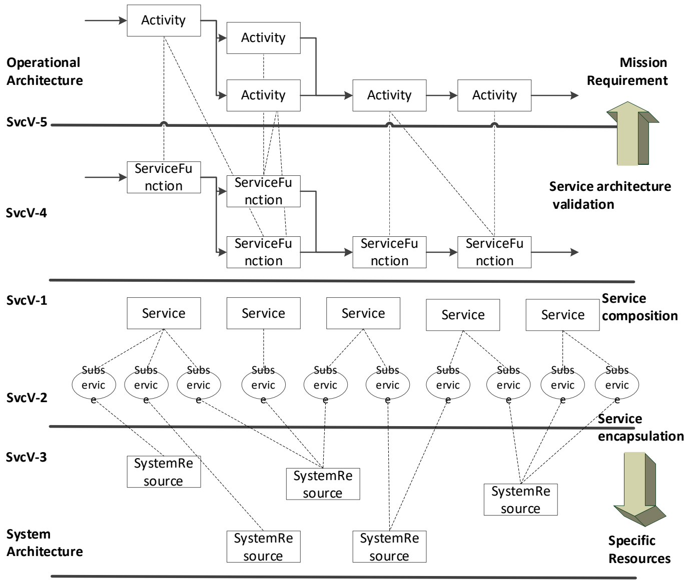

Figure 2 –Service View Thought

2.2 Introduction to Avionics System Service Architecture Model

The basic process of service architecture modeling is shown in Figure 3. The service architecture include following product models: service interface representation model (SvcV-1), service resource flow representation model (SvcV-2), service and system matrix (SvcV-3a), service function representation model (SvcV-4), service and activity tracking matrix (SvcV-5), service event tracking representation model (SvcV-10c) and service state transition representation model (SvcV-10b). The specific products are as follows.

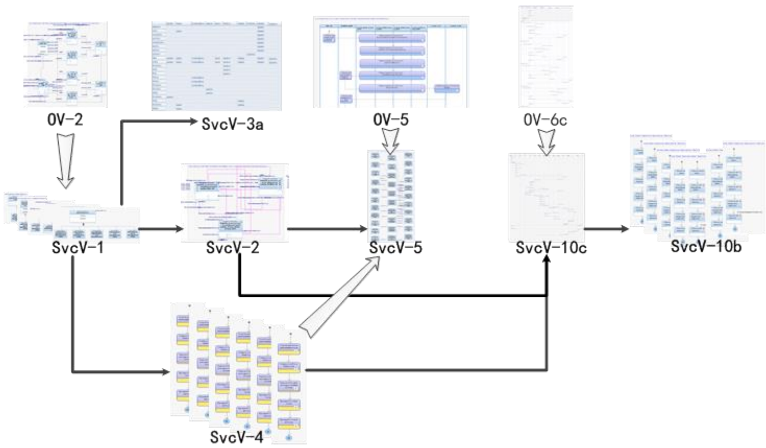

Figure 3 –Service Architecture Modeling Process

(1) Service Interface Representation Model (SvcV-1)

Svcv-1 describes the services, service items and their interconnection relations, which is used to define service concept, define service options, obtain service resource flow requirements, prepare capability integration plan, manage service integration transactions and prepare task plan (define capabilities and actors). Svcv-1 takes on the OV-2 resource flow description view, determines the services and service interfaces contained in all resources, and finally outputs the service interfaces and services by analyzing the resources involved in the task.

(2) Service Flow Representation Model (SvcV-2)

Svcv-2 describes the resource flows that need to be exchanged between services, which is used to standardize resource flows. Svcv-2 takes on OV-2 resource flow view and Svcv-1 service interface view. Through analyzing the interaction relationship of resource flow, it determines the resource interaction relationship between service interfaces residing on resources, and finally outputs the resource interaction relationship between service interfaces.

(3) Service and System Matrix (SvcV-3a)

SvcV-3a describes the relationship between various systems and services in a specific "architecture description", which is used to summarize the interoperability characteristics of system and service resource interaction, interface management, and comparison solution options. SvcV-3a takes on SvcV-1, analyzes the resource composition of specific architecture, and deploys services. It is the bridge between service layer and resource layer, and finally outputs the mapping matrix between services and system.

(4) Service Function Representation Model (SvcV-4)

SvcV-4 describes the functions implemented by services and service data flows, which are used to describe task job flows, identify service function requirements, decompose service functions, and associate relevant personnel and service functions. SvcV-4 takes on SvcV-1, analyzes the service functions that each service can realize according to the professional knowledge, and finally outputs all the service functions.

(5) Service and Activity Tracking Matrix (SvcV-5)

SvcV-5 describes the mapping between each service (activity) and the task activity (activity) they support, which is used to track service functional requirements and user requirements, track solution options and requirements, identify overlaps or gaps. SvcV-5 takes on OV-5 and SvcV-4, automatically generates the column vector of the matrix according to the activities in OV-5, automatically generates the row vector of the matrix according to the service function in SvcV-4, fills the mapping relationship between the activities and the service function into the matrix elements, and finally outputs the mapping relationship between the activities and the service function.

(6) Service Event Tracking Representation Model (SvcV-10c)

SvcV-10c describes the precise order of specific events of services, which is used to analyze resource events affecting tasks (business), analyze (dynamic) behaviors, and identify non-functional system requirements. SvcV-10c takes on OV-6c, SvcV-2 and SvcV-4. According to the event sequence in OV-6c and based on the resource interaction relationship in SvcV-2, the service function in SvcV-4 is refined into the sequence diagram of service access, and finally the service function call sequence based on service access is output.

(7) Service State Transition Representation Model (SvcV-10b)

Svcv-10b describes the response of services to events, which is used to define states, events and state transitions (behavior modeling) and identify constraints. SvcV-10b takes on SvcV-10c. Based on the sequence of service function calls, it draws the state machine conversion of each service access, which drives the dynamic simulation of the model, and finally outputs the state machine conversion model of each service access. According to all combat activities in svcv-5, a service template library is formed, and the full coverage of combat activities can meet the requirements of combat tasks. At the same time, it serves as the basis for subsequent system resource encapsulation to form sub services, and lays the instantiation foundation for sub service encapsulation.

3. Service Architecture Modeling Method and Core Key Technology

3.1 Service Architecture Modeling Method

Based on the service view design idea and process, combined with the requirements of multi platform avionics system, the service-oriented multi platform avionics system architecture design is studied. The research idea is shown in Figure 4.

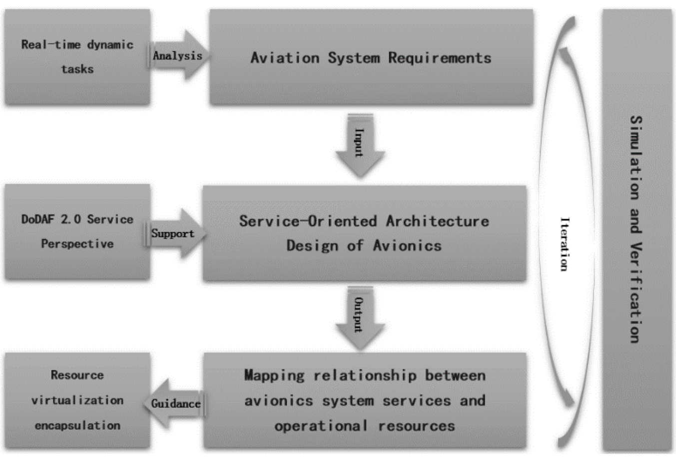

Figure 4 –Design Process of New Avionics Architecture

The requirement of the avionics system obtained from real-time and dynamic task analysis is taken as input; the service-oriented avionics architecture design is carried out by using the service perspective design method in DODAF 2.0; the mapping relationship between the avionics system service and combat resources is output to guide the virtual encapsulation of combat resources. Thus decoupling the binding of tasks and resources not only meets the top-down and dynamic task requirements, but also meets the bottom-up and flexible resource allocation, which provides an effective guidance for the design and development of open avionics system.

3.2 Core Key Technology

In the process of designing a new service-oriented avionics architecture, it is necessary to break through the following core key technologies: the automatic acquisition technology of avionics system requirements in the complex battlefield environment, the dynamic adaptive avionics architecture design technology, the service mapping and packaging technology of the avionics resource function, and the simulation and verification technology of the new avionics service architecture.

(1) The automatic acquisition technology of avionics system requirements in the complex battlefield environment

Firstly, the top-down method is used to divide the typical mission phases according to the "OODA" ring, analyze all the operational activities needed to complete the mission and the interaction between them. Then, according to the avionics professional knowledge, the avionics system service needed to be invoked is analyzed for each operational activity. Finally, the main services of the avionics system are classified and summarized to form the logical service partition of the service access of the avionics system, and the interface and attributes of the services are added.

(2) The dynamic adaptive avionics architecture design technology

Undertaking the requirements of avionics system and logical service partition, further analyze the specific service function description according to the service access process in the avionics field. Based on the service view framework of DoDAF2.0, the service architecture model of avionics system is designed and established.

(3) The service mapping and packaging technology of the avionics resource function

Undertaking the service architecture model, mapping and packaging the service function and system resource function of avionics system is carried out according to the functions and capabilities of existing avionics system resources. Due to the variety of mapping methods, the resource deployment scheme of avionics system is flexible and variable. When the resources of the avionics system change (such as the failure of one avionics resource), modify the mapping matrix between service function and system resource function, and package other avionics system resources with the same function into such services.

(4) The simulation and verification technology of the new avionics service architecture

The service architecture model is simulated and verified from the aspects of syntax, semantics and pragmatics of software language. Based on task requirements, the service architecture model is repeatedly iterated to ensure its logical rationality self-consistency and feasibility.

4. Multi-Platform Avionics System Service Architecture Modeling Case

Design a typical scene of civil unmanned aerial vehicle cluster joint rescue: the civil unmanned aerial vehicle cluster preloads the rescue task on the ground. After taking off, under the command of the ground station, it carries out air assembly networking and establishes communication, and returns for recovery after completing the rescue search task.

Based on the above scenarios, analyze and extract task activity and interaction information, and conduct operation view modeling, including high-level concept diagram OV-1, node connection diagram OV-2, information exchange matrix OV-3, organization relationship diagram OV-4, activity model OV-5, state transition description OV-6b and event tracking description OV-6c.

According to the interaction process between civil unmanned cluster, ground station and passenger plane in ov-2, it can be analyzed that civil UAV should include communication service, task loading service, flight management service, sensor management service, aircraft status monitoring service and so on; According to the professional knowledge in avionics field, the above services can be divided into sub services. For example, communication services can be divided into key management sub services, data communication sub services, satellite communication sub services, link management sub services, etc. the relationship between services and their sub services is summarized and integrated to form a SvcV-1 model, as shown in the figure below.

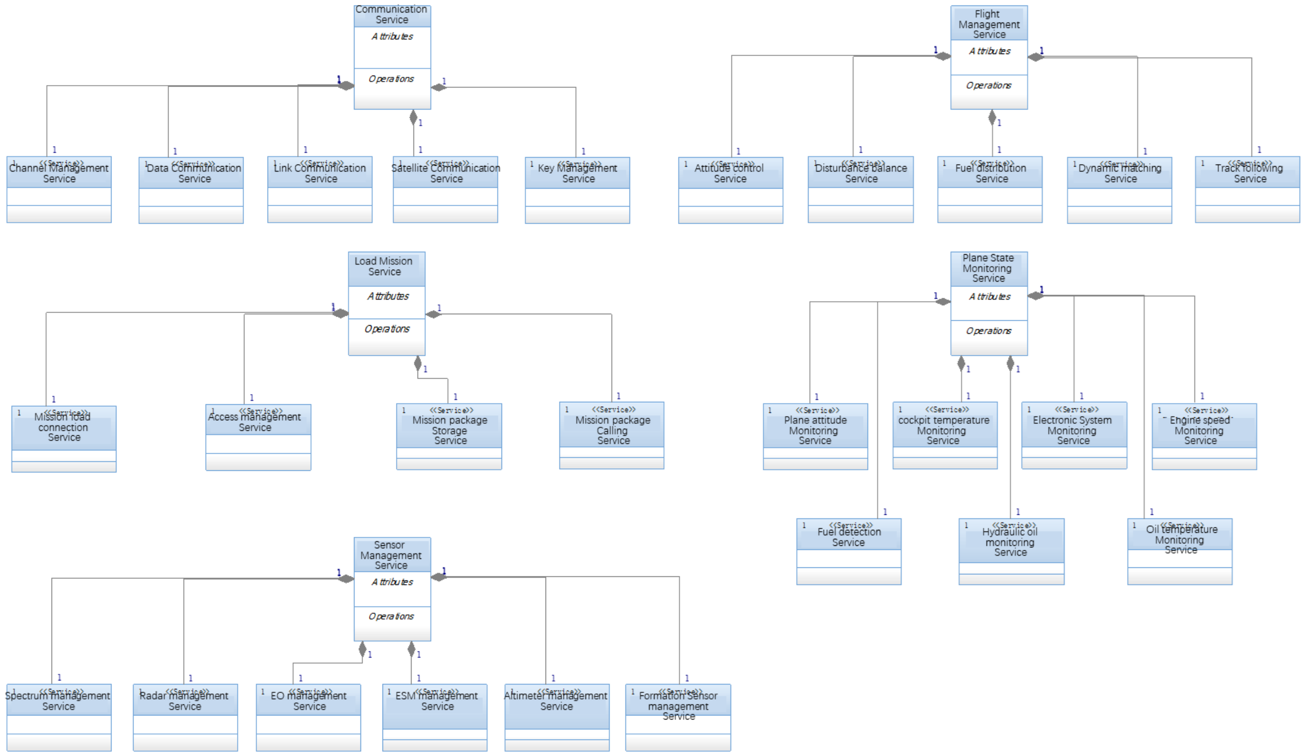

Figure 5 –SvcV-1 Model

Generate the service resource flow SvcV-2 model according to the resource flow, as shown in the following figure.

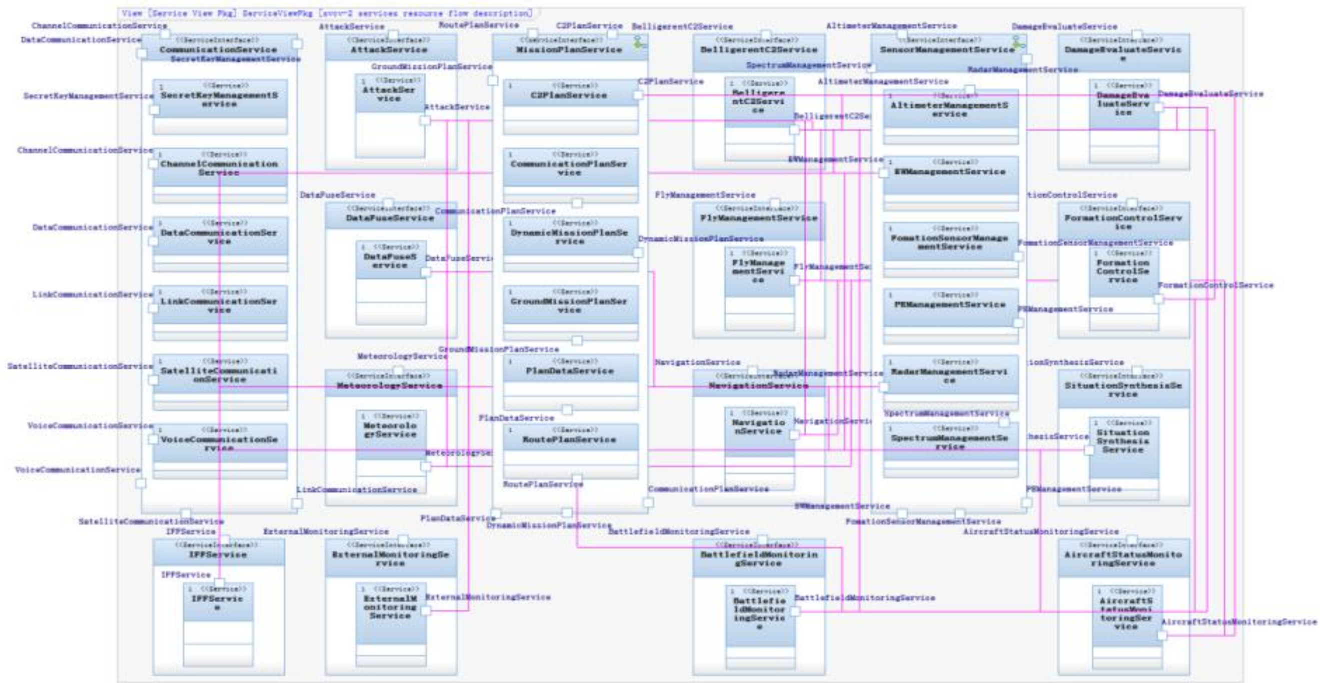

Figure 6 –SvcV-2 Model

According to the professional knowledge, analyze the functions realized by the service and form the SvcV-4 model.

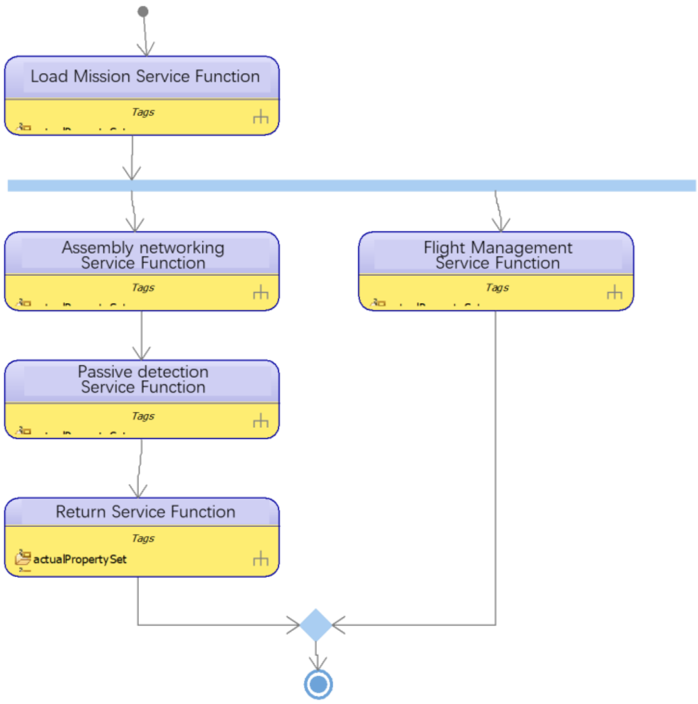

Figure 7 –SvcV-4 Model

At the same time, service and system mapping is formed according to the composition of underlying system resources, and the SvcV-3a model is generated, as shown in the table below.

Table 1 -SvcV-3a Model

System Service	Flight control system	Communication System	Photoelectric Wide Area Detection Equipment	Electronic Reconnaissance and Search Equipment	Multi Function Radar	Integrated Processing Unit	…
Key Management		●					
Satellite Communication		●					
Data Communication		●					
Channel Management		●					
Link Management		●					
Radar Management					●		
EO Management			●				
Electronic Search Management				●			
Altimeter management	●						
Formation Sensor Management						●	
…	…	…	…	…	…	…	

Define the mapping relationship between service functions and activities to generate SvcV-5 model, as shown in the following table.

Table 2 - SvcV-5 Model

To: OperationalActivity Scope: OperationalViewPkg

From: ServiceFunct	MissionLoadAct	NetAct	DetectAct	ReturnAct
MissionLoadSf	MissionLoadAct			
FlightManagementSf		NetAct	DetectAct	ReturnAct
DetectSf			DetectAct	
ReturnSf				ReturnAct
NetSf		NetAct		

Describe the timing of service access process according to the task process, dynamically verify the timing logic through state machine transformation, and generate SvcV-10c and SvcV-10b models.

Finally, taking the civil unmanned cluster joint rescue concept prototype demonstration scenario, task requirements and services as input, undertake the service architecture model, decompose the services corresponding to task activities into the functional disciplines of the system, and form the capability requirements of unmanned system. The equipment system requirements acquisition method based on architecture design obtains the requirements information from the aspects of task, system and technology, realizes the mapping from task requirements to service requirements to resource system requirements, corresponds the capability requirements proposed in the task with the functional requirements of resources in the system, and leads the function design through the system capability, The whole requirement acquisition and analysis process corresponds to the architecture product design process, which is in line with the idea of capability based and top-down.

5. Conclusion

This research of new service-oriented avionics system architecture, adopts the design idea of "operational task- service architecture-system resource", realizes the decoupling of operational tasks and avionics resources, provides effective support for the integrated design of flexible and modular avionics systems, greatly improves the efficiency of system design, shortens the research and development cycle, and saves development costs. This paper comprehensively describes the process, steps and core technologies of the new architecture design method. The next step should continue to study the implementation technologies such as service partitioning granularity analysis, resource virtualization encapsulation mechanism, so as to realize the specific development of the architecture to the avionics system.

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