Architecture Design of Flight Test Mission System Based on DoDAF

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Abstract: Flight testing is an important step in the development and testing of aircraft weapon equipment. The ability to develop a scientific and effective flight test mission architecture is essential for increasing flight test efficiency. Based on this, the article uses DoDAF theory to develop and study the architecture of the flight test mission system. First, the study examines the DoDAF theory and the requirements of the flight test mission system; second, the perspective structure model, which includes the flight test mission system architecture, is developed using business activity decomposition and mapping. Lastly, the flight test mission system's overarching structure is created. The research in this paper can provide theoretical support for the top-level optimization design of flight test mission system, and has potential application value.

Key words: DoDAF, flight test mission system, viewpoint model, architecture

1 Introduction

Flight testing is the process of testing and data testing aircraft weapon systems in a real-world flying scenario. The actual and complete data gained during flight testing may compensate for the limits of theoretical calculation and ground testing, and can be utilized to validate the design logic, index realization, and quality dependability of aviation weapons and equipment. It can assist the continual improvement and optimization of the development process by comparing and referencing theoretical calculations and test results [10]. As the complexity and quality requirements of aircraft weapons and equipment increase, so do the needs for flight testing. As the core business of flight test, flight test mission system is a complex large system. Through the overall design of the flight test mission system architecture, make it more scientific and reasonable, progressive, interlinked and orderly, so as to improve the efficiency of flight test and meet the needs of future aviation weapons and equipment development [6], which is the focus and hotspot of current research.

The architecture outlines the system's composition, interdependence, and appropriate rules and criteria to guide the top-level design [3]. The Department of Defense Architectural Framework (DoDAF) [1] is a widely used architecture framework. DoDAF-based architectural modeling is now being extensively researched. Document [5] offers a static modeling approach of equipment system of systems mission based on activity modeling with the support of DoDAF theory, and uses an aircraft carrier system mission as an example to demonstrate the usefulness of the suggested method. The literature [2] explains and evaluates the modeling method of the DoDAF2.0 architecture, which may give technical assistance for the system development

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process's optimization design, modification effect analysis, and risk control. Literature [9] determines the modeling method and development steps of the combat view product based on DoDAF. The results provide theoretical support for understanding the internal laws of the command-and-control system and conducting the research on the top design of the command-and-control system. At the same time, it is also of referential significance for the research on the architecture of diversified systems. Wang et al. [8] visually modeled the on-orbit service of space robots based on the DoDAF architecture modeling method, and obtained a typical battle view product, which has certain reference value for the research of on-orbit service of space robots.

It is not difficult to identify that present research is primarily concerned with modeling, analysis, and testing of things such as battle view products and equipment system of systems jobs. Moreover, the DoDAF architectural framework offers the architecture model's description rules and recommendations but does not give a specific system design approach. There is no study on the overall design of the system architecture for the flight test mission system of aviation military equipment. As a result, within the framework of DoDAF architecture, research on the overall architectural design of flight test mission system is a critical topic to be addressed in relevant domains, with far-reaching research implications.

DoDAF is the most researched and utilized architecture framework in the military area. It is a generic architecture that acts as a guide and top-level conceptual model for the construction of architecture. While creating the architecture for each mission area, the US military mandates the Department of Defense to enforce the DoDAF's approach to architectural description.

The DoDAF framework has gone through several version modifications, including 1.0, 1.5, and 2.0, and its architectural development mindset has moved from product-centric to data-centric. DoDAF V2.0 completely realizes the fundamental concept of data-centric architectural development [7].

Inspired by the above analysis, the article uses DoDAF's design ideas and description methods for reference, establishes the viewpoint model and designs the overall structure framework by analyzing and describing the system composition and system functions of the flight test mission system. The results can provide feedback, guidance and support for the optimization and adjustment of flight test mission system, and lay a good foundation for the system research of other flight test systems.

2 Architecture modeling theory based on DoDAF

The United States Department of Defense created the DoDAF system architectural framework. It is used as a system engineering approach to assist the architectural design of complex systems. C4ISR is the initial architectural framework issued by the United States (Command, Control, Communication, Computers, Intelligence, Surveillance and Reconnaissance). DoDAF1.0, DoDAF1.5, DoDAF2.0, DoDAF2.0, and more systems have been issued consecutively as research has been deepened and practice has been applied. The system architectural framework is centered on services and data, and it is made up of eight views and 52 models, as shown in Table 1 [4]. In practice, suitable model customization for individual research objects can match the system modeling needs.

Table 1 Eight Viewpoints of DoDAF Theory and Their Corresponding Functions

Viewpoint name	Primary coverage	Effect
All viewpoint (AV)	Summary information, comprehensive dictionary	Describe the top-level content of the architecture related to all viewpoints
Data and information viewpoint (DIV)	Conceptual data, logical data, physical data	Describe the architecture content data relationship and structure
Standards viewpoint (Std V)	Standard overview, standard forecast	Describe the standards, specifications and development forecast of the architecture
Project viewpoint (PV)	Portfolio relationship, time schedule, capability mapping	Describe the relationship between operational capability requirements and projects
Operational viewpoint (OV)	Advanced operational concept diagram, operational resource flow description, organizational relationship diagram, etc	Describe operational scenarios, processes, activities and requirements
Capability viewpoint (CV)	Conception, capability classification, capability stage rules, capability dependence	Describe the top-level content of the architecture related to the viewpoint
Services viewpoint (Svc V)	Service environment description, service resource flow description, service function description, etc	Describe performers, activities, services and their interactions
System viewpoint (SV)	System interface description, system resource flow description, system index matrix, etc	Describe the composition, interconnection and environment of the system

The article chooses four viewpoints when designing the system structure of the flight test mission system using DoDAF theory, namely, panoramic viewpoint, capability viewpoint, combat viewpoint, and system viewpoint, based on the mission requirements, capabilities, and system functions of the flight test mission system system. The overall architecture design of the flight test mission system is then completed using five models from the four viewpoints: overview and summary (AV-1), high-level business concept map (OV-1), business activity decomposition tree (OV-5a), capability and business activity mapping (CV-6) and system function description (SV-4).

3 Architecture framework and modeling steps

Scientific design and efficient modeling of flight test mission system architecture may considerably increase flight test efficiency and the degree of development of aviation weapons and equipment. The DoDAF model incorporates table, structure, behavior, mapping, ontology, image, and time progress types. Of them, behavioral models are mostly used to explain the dynamic behavior features of architecture, whilst other types of modelling are primarily used to describe the static structure aspects of architectural pieces. To increase modeling efficiency and accuracy, the subsystem is split according to the flight test mission type while building the model of flight test mission system architecture based on DoDAF theory.

3.1 Overall framework

The concept of the overall architectural design of the system is to construct the system's general structure. As a result, the broad structure of the flight test mission system is initially designed in this study. According to the flight test mission's whole life cycle, the flight test mission system is primarily consists of three subsystems: mission design system, mission control system, and mission support system.

In the aforementioned subsystems, the mission design system carries out the flight test mission design. The function and performance index verification of the aircraft platform, power unit, airborne equipment, and other test items is achieved through the modification and testing of the test machine. The task management and control system monitors and analyzes the task execution status and outcomes, grasps the technical state of the test object in real time, and offers a decision-making foundation for task planning. The mission support system helps the flight test mission run smoothly by providing maintenance support such as flight preparation, boarding operation, and landing reception, field support such as equipment maintenance, command and guidance, weather forecast, and comprehensive support such as medical service, power service, and fire service. The composition of the flight test mission system is given in Fig. 1.

Furthermore, when developing the general framework of the flight test mission system architecture, the complicated coupling relationship between view sets should be taken into account. They can be termed unconnected views if there are no overlapping components in the view collection. In this situation, the model is unaffected by the sequence of view development. When there are dependencies or dependencies between views, the dependent views should be taken into account first while building the model. Simultaneously, when models are in a collaborative relationship, they should be built and altered repeatedly. Based on the identified model group, the above development order may be used to identify the order of model establishment.

3.2 Design steps

This article discusses and models the goal architecture from the perspectives of panorama view, activity view, capability view, and system view while creating the architecture model of a flight test mission system based on DODAF theory. The following are the particular steps:

Step 1: Write a summary description. The top-level information of the flight test mission system, such as the scope, background, purpose, constraints, test contents, measurement indicators, task sources, and needed resources, will be specified using AV-1 as a planning guide for the building process of other models.

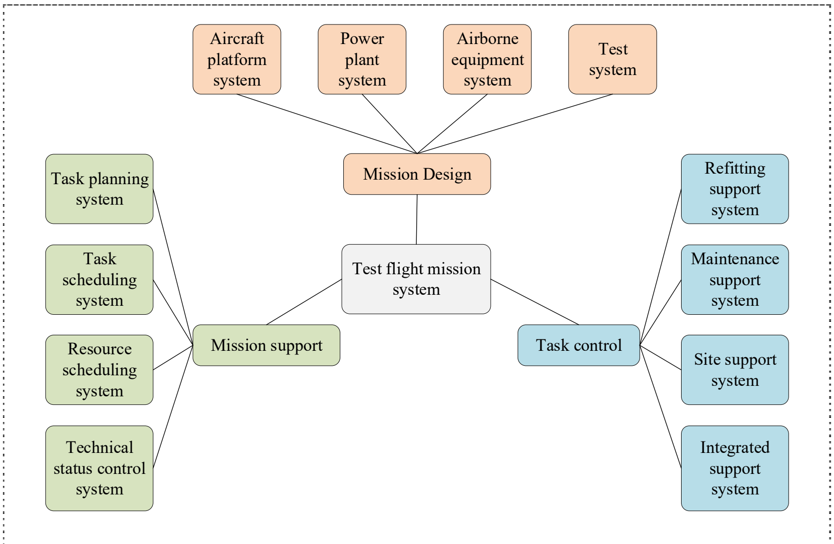

Fig. 1 System composition of flight test mission system

Step 2: Provide a general description. The overall, intuitive, and clear business process description of the flight test mission system from a macro perspective is provided by OV-1, which acts as a bridge between the decision-maker and the designer, allowing the designer to understand the flight test mission system from various perspectives.

Step 3: Describe the activity. The business activities of the flight test mission system are dissected from top to bottom using OV-5a, according to the various stages of the flight test mission's whole life cycle, in order to build a dynamic interaction between the activities and other elements.

Step 4: Create the mapping matrix. Sort the capability list of the flight test mission system using CV-6, and create a mapping link between business activities and capabilities to verify that business activities fulfill the requirements of realizing capabilities. Step 5: Describe the function. The flight test mission system function tree is developed using SV-4 to identify the common system functions, which serves as the foundation for the following design of the system resource flow and data flow.

4 Viewpoint structure model of flight test mission system

Flight test mission system, as the main business of flight testing, may increase theoretical support for the progressive design of aviation warfare equipment. The related perspective structure model may be swiftly constructed by examining the dynamic behavior and structural properties required by the flight test mission system.

4.1 Overview and Summary AV-1

AV-1 is the general and summary description of the flight test mission system's input information, and it serves as a foundation for the description of additional perspectives and model information. The scope, context, goal, limitations, test content, measurement indications, task sources, and resources required are all described in AV-1. AV-1 can give sufficient information assistance for corporate decision makers, as seen in Fig. 2.

4.2 High-level business concept diagram OV-1

OV-1 graphically defines high-level business operations, as well as the business purpose and architecture, as well as the interaction between the architecture and external systems. Organize the dispatcher to provide instructions for the modification, maintenance, and field maintenance to carry out the preparation work prior to the execution of the flying mission. Simultaneously, resource scheduling allocates the necessary resources to the three systems.

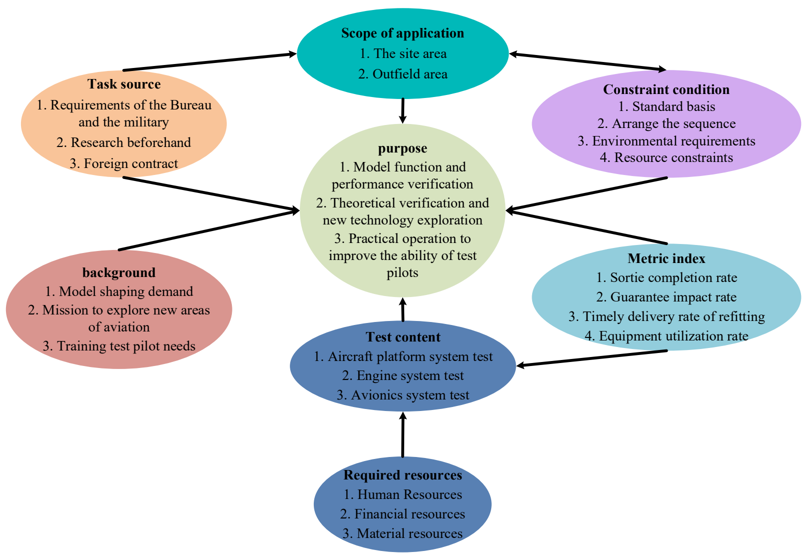

Fig. 2 High level overview and summary of flight test mission system AV-1

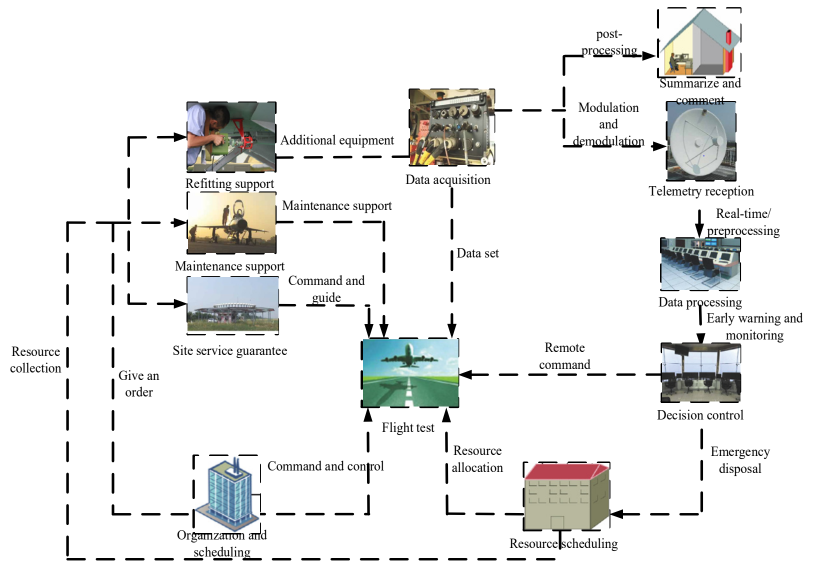

Fig. 3 High level business concept diagram of flight test mission system OV-1

Some of the data acquired during the flying mission will be analyzed afterwards, and part of the data will be processed in real time/pre-processing following modulation and demodulation to provide reasonably efficient and accurate decision control. When the flight mission is completed, the test data will be analyzed to give the foundation for the sortie report. The overall structure designer can completely comprehend the flight test mission system thanks to OV-1, and its structure is represented in Fig. 3.

4.3 Business Activity Breakdown Tree OV-5a

The term OV-5a refers to the business operations of the flight test mission system. The model decomposes business operations layer by layer using a hierarchical tree structure. The flight test mission system's business operations are organized into four stages throughout operation: flight test project approval, flight test design, flight test implementation, and flight test summary. Following then, it will be further degraded, and so on. Following the decomposition layer by layer, the business activity decomposition tree will be constructed, offering clear and effective ideas and solutions for the flight test mission. Its structure is depicted in Fig. 4.

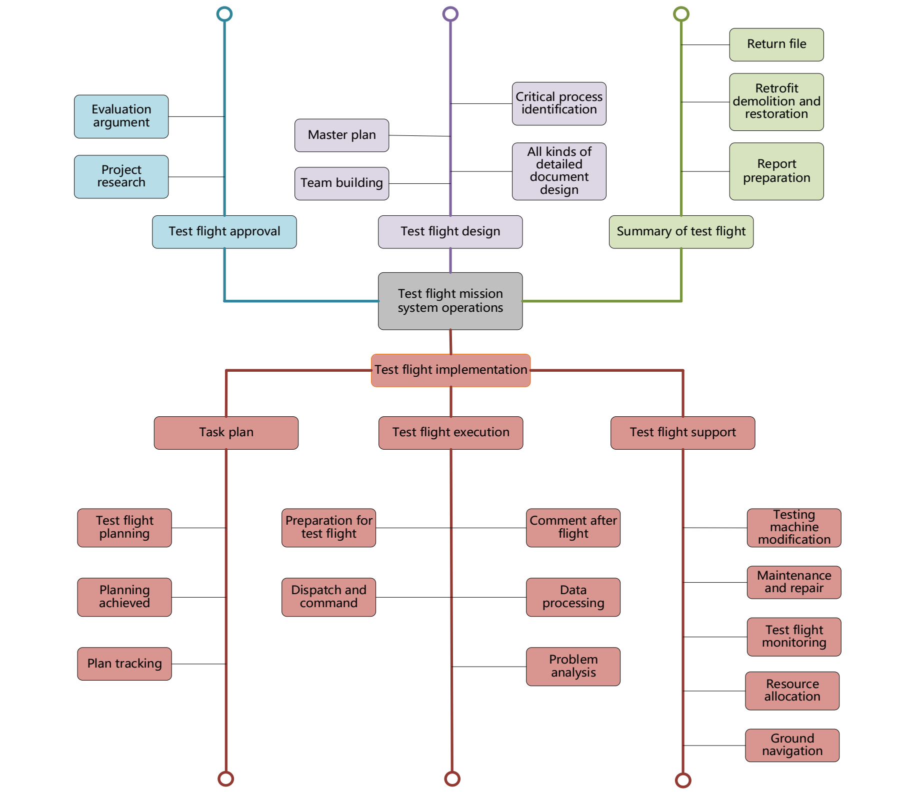

Fig. 4 Operational Activity Decomposition Tree of Flight Test Mission System OV-5a

4.4 Capability and business activity mapping CV-6

CV-6 is used to define the mapping link between business activities and flight test mission system business capabilities. The flight test mission's system capability consists primarily of five capabilities: correct reaction to mission requirements, comprehensive mission planning and optimization, effective mission scheduling, comprehensive mission status control, and efficient mission support:

a) Correct reaction ability to task requirements: establish accurate decomposition of test requirements based on the requirements of relevant standards, and guarantee that the test design, implementation, and assessment respond to the test requirements.

b) Comprehensive mission design and optimization capability: according to flight test requirements, comprehensively coordinate the dimensions of test, modification, and comprehensive maintenance, realize the efficient integration of flight test tasks at different stages and disciplines, improve sortie capacity, reduce flight test cost, and shorten the flight test cycle.

c) Task efficient scheduling capability: the efficient operation of flight test business processes can be realized through the rational allocation of flight resources and the overall deployment of flight tasks, the test preparation cycle can be shortened, the operational efficiency of scheduling work can be improved, and the effective utilization of resource efficiency can be promoted.

d) Complete mission status control capability: trace and track the state of the whole test mission process, enhance the degree of refined control and real-time decision optimization through accurate test mission status evaluation. e) Mission-efficient support capability: maintain the safe operation of the test flight and accomplish speedy, efficient, and high-quality completion of the test machine's test flight support mission through intelligent management of the test machine and the test field. When the system architecture model of the flight test mission system is constructed using DoDAF theory, the aforementioned system capabilities may be described as a matrix. As illustrated in Tab.2, use " to indicate that the flight test activity directly supports the capability.

Tab 2 Flight Test Mission System Capability and Activity Mapping Table OV-5a

Flight test mission	Test flight activities	Accurate response ability to task requirements	Mission integrated design and optimization capability	Efficient task scheduling capability	Comprehensive control ability of task status	Mission efficient support capability
Test flight project approval	Project research	√				
	Evaluation and demonstration	√				
Flight test design	Team building					√
	Master plan	√	√			
	Detailed design	√	√			
	Key process identification	√				
Flight test implementation	Planning	√			√	
	Plan release				√	
	Plan tracking				√	
	Flight test preparation					√
	Command and dispatch			√		
	Post-flight comments				√	
	Data processing				√	
	Problem analysis				√	
	Test machine modification					√
	Maintenance and repair					√
	Flight test monitoring				√	√
	Resource allocation			√	√	√

	Ground navigation			√
Flight test summary	Report preparation	√	√	
	Modification removal and restoration			√
	File archiving		√	

4.5 System function description SV-4

SV-4 decomposes the system of system functions of flight test mission layer by layer in the form of tree diagram. The system function of flight test mission can be divided into six functions: demand management function, mission design function, command and dispatching function, comprehensive support, data management and analysis and evaluation function. In practical application, each function can be subdivided into corresponding sub-functions. This paper only introduces the general functions of the flight test mission system, and the specific detailed functions will not be discussed temporarily, as shown in Fig. 5.

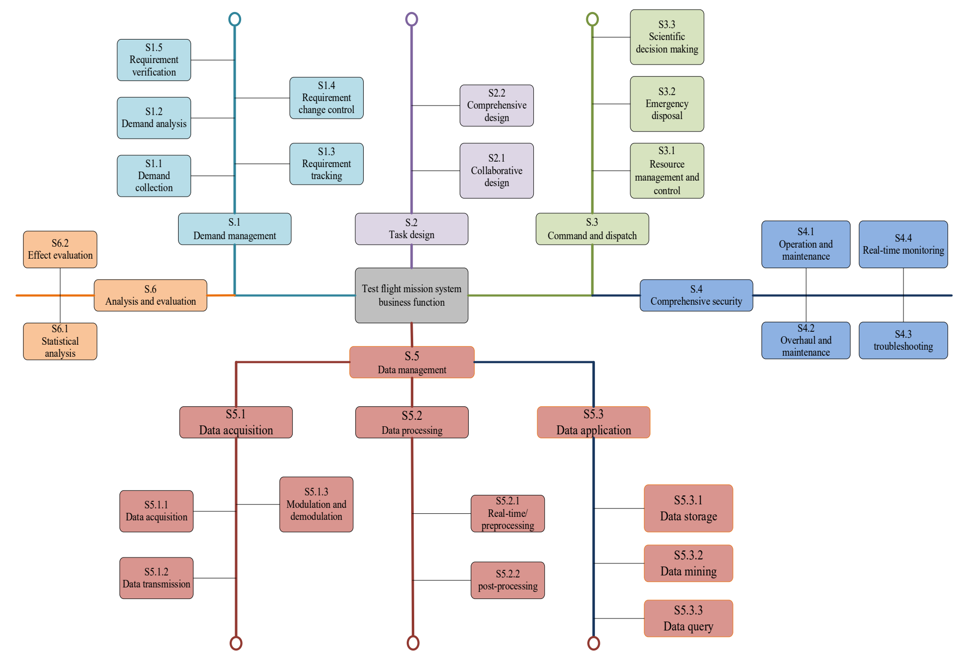

Fig. 5 Flight Test Mission System Function Description SV-4

5 Conclusion

This article uses the DoDAF theory to build and investigate the flight test mission system architecture as the research object, focusing on the process of project establishment, design, implementation, and summary of the flight test mission system. The appropriate perspective structure model is built by analyzing DoDAF theory and the requirements of the flight test mission system. The five models of panorama view, activity view, capability view, and system view are primarily discussed, and the entire architecture of the flight test mission system is built around them. The study findings in this work can serve as a theoretical foundation and technological assistance for the development of various perspective models, as well as have prospective practical prospects.

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