High-Frequency Data Link System Architecture Design based on SysML Modeling Language

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Abstract. This article is to show a new type of aircraft system design method, which decomposes the civil aircraft high-frequency data link system architecture into functional architecture, logical architecture, and physical architecture, and describes the hierarchical relationship between the function, logic, and physics of the system through the SysML modeling language. This article shows the method of converting the traditional high-frequency data link system design work based on experience and documents into model-based architecture design work. It uses the association and traceability of the model to ensure the integrity of the information in the design process and achieve the purpose of fast and convenient system design.

1. Introduction
The scale and complexity of modern civil aircraft airborne systems are getting higher and higher, leading to many design problems in the architecture design process of modern aircraft. The process of traditional architecture design is carried out in the minds of designers, and the design results are recorded and transmitted in the form of documents. However, with the complexity of the system, the text has many defects in describing the logic, composition, and interface of the complex system. Therefore, carrying out system architecture design through modeling is the development direction of aircraft system design. System architecture modeling refers to the use of models to express the composition and interfaces of each layer of architecture, and to use the model's relevance, traceability, and other functions to improve design efficiency.

This paper proposes a civil aircraft data link system architecture design method based on a specific modeling language (SysML language), which converts the traditional experience and document-based design work into a model-based architecture design process, starting from the flight scene definition, constructing the function, logic, and physical architecture model of the data link system clearly expresses the system function and architecture composition and key performance parameters in a modeled manner.
2. Architecture Design Method

The architecture design of the aircraft high-frequency data link system in this article was born out of the model-based system engineering (MBSE) method. Model-based system engineering is currently an effective means to deal with complex system design. It is currently increasingly used in aviation, aerospace, automotive and other industries, including foreign NASA, Boeing, Lockheed Martin, etc. And domestic research on MBSE is also being carried out gradually. The most essential difference between MBSE and the traditional system engineering design method is that it replaces the traditional natural language-based document design by means of modeling and digital design expression. Since the digital model can be parsed and processed, it provides a basis for the automation of the design process, including data management, data storage, data analysis and data transmission.

The implementation of MBSE requires three aspects of support: methodology, system modeling language and design tools (software). MBSE methodology is a design guide for design expression through models, covering processes, data and design tools. The system modeling language is a standard description language of model design, which realizes the standardization of design expression. At present, the mainstream system modeling language in the industry is SysML (Systems Modeling Language), developed based on the software architecture design language UML, and is jointly maintained and released by the Object Management Group and INCOSE.

In this paper, the aircraft high-frequency data link system architecture design method follows the above-mentioned basic principles of model-based system engineering design, combined with specific methodology, SysML language and modeling design tools, digital design and analysis of the system architecture model, and for the follow-up based The in-depth value mining of digital model data provides a foundation.

3. Architecture Design Path

This architecture design introduces the SysML model language. The SysML language is a language specification that contains a variety of modeling elements. These modeling elements are mainly classified by nine types of diagrams, and each diagram only reflects part of the system design characteristics. This article tailors the use case diagram, activity diagram, block definition diagram (BDD) and internal block diagram (IBD) in the SysML language to design a complete high-frequency data link system architecture.

This architecture design chooses use case diagrams to describe the top-level tasks and basic external functions of the aircraft, and uses activity diagrams to describe aircraft scenarios to clarify functional behavior requirements. Then it further describes the functional behavior of the high-frequency data link system.

After completing the system use case scenario, build BDD diagrams and IBD diagrams to describe the boundaries and interfaces between the modules of the system in the form of graphics for the data link system architecture, including the definition and description of the components of the system. Among them, the BDD is used to decompose the system. The tree structure in BDD is used to express the number of internal modules of the data link system. And the IBD diagram is used to describe the cross-linking relationship (interface relationship) between the internal modules of the system, and finally the structure of the high-frequency data link system is completed as a architectural model.
decomposed, and the logical relationship between several sub-functions in each horizontal hierarchical level. Logical architecture describes functional groupings, adopts specific logical components to undertake functional architecture, reflects the connection relationship and data interface relationship between logical components, and describes the logical program definition of the system. The physical architecture describes the hierarchical relationship, cross-linking relationship and signal/material interaction between devices, a hierarchical organization of software/hardware components and their related interfaces, and can describe the physical definition of the system.

4.1. High-frequency Data Link Scenario Definition Based on SysML

First, according to the top-level tasks of the aircraft, use the use case diagram to describe the scenarios and use-related parties of the aircraft's high-frequency data link function (see Figure 1).

**Figure 1. High-frequency Data link Use Case Diagram**

Then use the activity diagram to mark the aircraft, pilots, and air traffic controllers in the form of swim lanes, and define functional activities in the swim lanes to capture high-frequency data link-related functions. Finally, the captured functions are expanded to capture all the sub-function activities that support the high-frequency data link communication function, and lay a solid foundation for the subsequent architecture design (see Figure 2).

**Figure 2. High-frequency Data link Activity Diagram**

4.2. High-frequency Data Link Functional Architecture Definition Based on SysML

After the high-frequency data link function related activities are captured, the BDD and Block elements based on the SysML language are used to transform the functional activities into functional
components, and the decomposition structure of the functional components is established. The BDD is shown in Figure 3, which describes the function Decomposition and composition relationship.

![Figure 3. High-frequency Data Link Functional Component BDD](image)

Formulate the interface definition rules of functional components based on SysML language. Clarify the interface type of functional components, distinguish input and output. According to the specific input/output content, it is divided into signal interface, material interface and energy interface, as shown in Figure 4. Based on the interface content, redefine the content of interaction between functional components in the functional architecture, which also includes three types of interaction items of signal, matter, and energy. As shown in Figure 5, some examples of interactive content definitions are given.

![Figure 4. High-frequency Data Link Functional Component Interface Definition](image)  
![Figure 5. High-frequency Data Link Functional Component Interaction Item Definition](image)

Based on the defined functional components and interfaces, the connection relationship between the functional components of the high-frequency data link is established in a modelized form. Clarify the content of the interactive items transmitted between functional components to form an IBD of the high-frequency data link functional architecture. As shown in Figure 6, the IBD of the high-frequency data link function is given.

![Figure 6. IBD of the high-frequency data link function](image)
4.3. High-frequency Data Link Logical Architecture Definition Based on SysML

The logic architecture of the high-frequency data link will adopt specific logic components to undertake the functional architecture, describing the distribution of the high-frequency data link functions to the logic components after grouping. Reflect the interface relationship and data transfer relationship between logical components, and complete the initial transformation from "function" to "system". Eventually achieve the role of defining the preliminary plan of the high-frequency data link system.

In the design process of the high-frequency data link logic architecture, in accordance with the design requirements of the functional architecture, combined with the mature design of the existing system logic architecture, the logic architecture design is carried out to form a logic architecture without redundancy. Based on the logic architecture without redundancy and considering the design features, safety and performance requirements of similar models, redundant components and redundant control logic are designed to form a logic architecture with redundancy.

The logical architecture design process based on SysML is similar to the functional architecture design. First, use the BDD to establish the decomposition relationship of logical components (see Figure 7), and then determine the interface and interactive item definition rules.
Based on the defined logical components and interactive content, the connection relationship between the logical components is established to form a logical architecture IBD. Figure 8 shows the IBD of the logic architecture components of the high-frequency data link system.

![Figure 8. High-frequency Data Link Logical Architecture IBD](image)

### 4.4. High-frequency Data Link Physical Architecture Definition Based on SysML

The physical architecture of the high-frequency data link system inherits the logical architecture. It is used as the input of the aircraft system design proposal which defines the relationship and interface form between the devices from the perspective of product realization.

In the process of physical architecture design, the definition of physical components is based on logical architecture and logical grouping. Logical grouping can be named according to the importance of logic, the complexity of logical associations, the degree of logical coupling, etc. Actually that is the definition of physical entities. As shown in Figure 9, it is an example of a BDD of the physical components of a high-frequency data link system.

![Figure 9. High-frequency Data Link Physical Component BDD](image)

Formulate physical component interface definition rules based on SysML language, clarify the interface type of functional components, and distinguish between input and output. According to the specific input/output content, it is divided into specific signal interface, material interface and energy interface, as shown in Figure 10.
Based on the defined physical components and interactive items of the high-frequency data link system, the connection relationship between the physical components is established. And clarify the content of the interactive items transmitted between the physical components to form an IBD of the high-frequency data link system’s physical architecture. As shown in Figure 11, the IBD of the physical components of the high-frequency data link system is given.

5. Conclusion
Aiming at the development characteristics of civil aircraft, this paper introduces the design method of aircraft high frequency data system architecture based on SysML model. The system composition, boundaries and interfaces are described in the form of models from multiple dimensions such as scenario definition, functional architecture, logical architecture, and physical architecture. A unified collaborative design relationship between system functions, logic and physical architecture is realized, and the design efficiency of the civil aircraft research and development process is improved, which has important guiding significance for the design of civil aircraft systems.
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