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The Integration Development Platform and Application of the Avionics System Based on the Model-Driven

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***Abstract*—This paper proposed an integration development platform of avionics system based on the model-driven method, including model-driven design, simulation, realization, integration and test. Through the applications and verification of the avionics system projects, this platform used the model-driven design to solve the problems of avionics system development, such as the long development cycle, heavy maintenance work, the complicated connection of all the development phases and the no reuse of design results. It could better adapt to the current requirements of avionics systems development.**

***Index Terms*—Avionics system, integration development platform, model-driven, V-mode.**

I. Introduction

The avionic systems of newly developed aircraft platforms are demanded to be a fully integrated avionics system of enhanced functions supporting the operator for successful mission operations [1]. The avionics system is the significant component of the aircraft design. The complexity and information comprehension of the modern avionics system have been increased greatly [2]. The comprehensive avionics system supports the highly shared resources, the efficient data fusion and the intensive software.

The development of the avionics system is a complicated project. With the development of the complexity and information comprehension of the modern avionics system, the design should solve the following problems:

1) The large scale of the system has a very complex connection, which leads to the difficulty for design and integration. Adopt the traditional waterfall design method can result in the low development iteration, high risk and long period cycle;
2) The output formats are mainly documents and code, so that the maintenance work is severe and the efficiency is low. Meanwhile, there will be mistakes during the information transfer;
3) The bad link of the system design, simulation and realization can cause no reuse of the design results. Meanwhile, using all the design tools scattered so that there is no integration development environment throughout all the design phases.

In order to solve the problems in the avionics system development, this paper analyzes the V mode integration development platform and application of the avionics system based on the model-driven. Because of the execution, verification and uniqueness of the modules, we build the integration development platform of the avionics system based on the model-driven. By this way, we realize the smooth transition and link during all the development. Then apply this platform into the real avionics system project and verify the feasibility further.

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II. The Model-Based V-Mode Avionics System Development Process

The traditional waterfall design method is based on the document from top to bottom. The design sequence should be executed strictly according to the project period cycle. Lack of the feedback within the design phases and using the results formed in document and code to transmit can lead to the severe maintenance work as well as the long iteration cycle. From all above, it cannot satisfy the requirement of the avionics system at the moment.

A. V-Mode Development Process

The V-mode development process is shown in Fig. 1. It is improved based on the traditional waterfall design, which highlights the full verification of the system in the analysis design phase and focuses on the effect of the feedback [3]. Using the V-mode development can discover the poor design and begin to iterate immediately. This method can enhance the quality of the analysis and design of the avionics system, as well as reducing the development risk and shortening the iteration cycle.

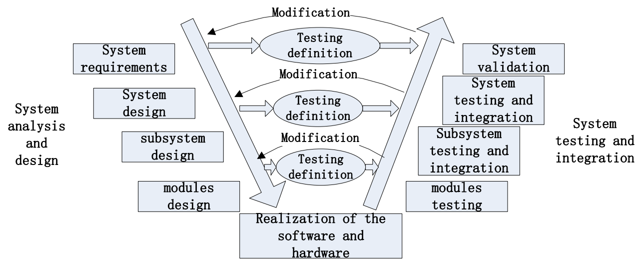

Fig. 1. V-mode development process.

In order to verifying the design results fast and effective, as well as keeping the consistency of the design and realization promptly and accurately. Therefore, the model-based development is the key to the V-mode development process.

B. Model-Based Design

Model-based design uses the modules to integrate the entire development process. It can verify and evaluate system for the function and performance at all the stages of development. Compared with traditional design methods based on the document and code, the model-based design fully satisfies the requirement of the V-mode development process, including early validation, full feedback and rapid iteration.

III. The Integration Development Platform Based on the Model-Driven

The integration development platform based on the model-driven is basis of the model-based V-mode development. It supports the avionics system design, simulation, implementation and integration. Mainly composed by the software tools and hardware devices of all stages of development, the system platform architecture is shown in Fig. 2.

A. System Design

The core content of system design contains ICD (Interface Control Document) design, DD (Detailed Design) design and POP (Pilot Operation Procedure) design.

1) ICD design

ICD describes the data interface of the subsystems and devices, which is the key output of the avionics system design throughout the cycle of design, development and testing of the avionics system.

In addition to the basic functions of the ICD management, collaborative development, version control and other, the model-based ICD design tools should also combine with the DD design and POP design. The ICD design supports the output of interaction logic of the avionics system top design and defines the uniform format for the logic.

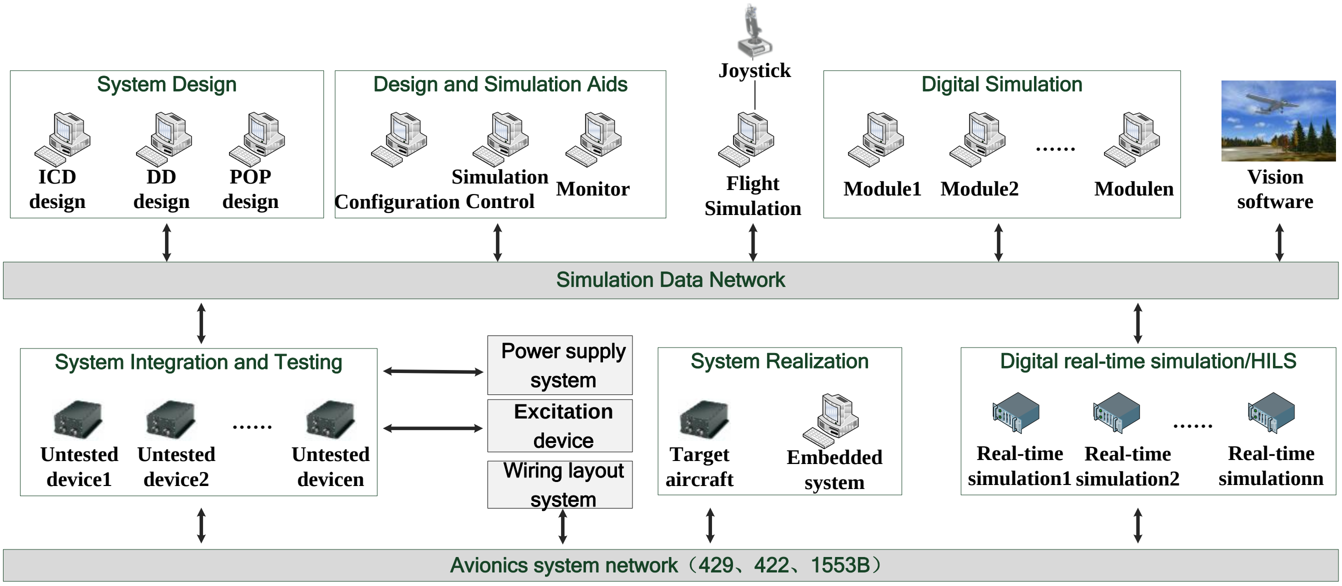

Fig. 2. System platform architecture.

2) DD design

DD design is the further detailed design for the business logic and interaction logic between the subsystems and devices after ICD design.

Rhapsody of IBM is an embedded software design tool, fully supporting the model-driven design process. Based on visualization features of UML/SysML, it achieves the business logic design of the subsystems through the flow diagram and state diagram, as well as the automatically code generation.

The interaction logic design of the subsystems needs to keep consistent with ICD. In order to solve the problems that the change of the ICD may lead to the disjoint design and poor link with DD design, the integration development platform uses the better design tools. It is based on the ICD design to automatically generate the Rhapsody static data model interface for the subsystems, which already contain the interaction logic implementation module matched with the ICD. Therefore, the designers only need continue to complete the specific business logic design on the basis of the model framework.

3) POP design

POP designs the system feature, the displays information and operational devices of the avionics system aspects of HMI, avionics systems feature that displays information, operational equipment and fashion design [4]. The goal of advanced cockpit display systems is to present large amounts of information quickly and in an understandable format, enabling the aviator to improve mission performance [5].

VAPS XT of Presagis is the widely used in the HMI design tool in the field of aviation instruments, which supports the rapid prototype design, code generation and the final embedded system transplantation of the display devices [6]. Using VAPS XT, the designers can complete HMI design and display logic design of the display devices. VAPS XT simulation tools will fundamentally change the development process of human-machine interface, and can reduces the design costs and shortens the design cycle [7].

The interaction logic design of the display devices should also keep consistent with the ICD. In order to guarantee the close link of the ICD design and POP design, the integration development platform uses the typical design tool, based on ICD, to bind the ICD data with the display elements by the graphical way. It automatically generates the POP model communication program, quickly realizes POP model and the data exchange between other models.

B. System Simulation

Use the system simulation to validate the design results and improve the system analysis and design quality through the multiple iterations. Because of the verification and execution, the quickly implementation of the simulation environment is the basis for the integration of design and simulation.

1) Simulation communications network

Since the large amount of the avionics devices, the communication between the simulation models will become more complicated at the full-system models simulation phase. Build the stable, high throughput and real-time simulation communication network is the key to the system simulation phase.

The integration development platform builds the communications network based on DDS (Data Distribution Service) middleware. DDS is the data standard in the real-time distribution system, which mainly used in the important fields of high performance, predictability and resource effective use [8]. Compared with the traditional TCP/IP protocol, DDS middleware helps to shield many basic problems in network communications and reduce the period from design to simulation [9].

2) Digital simulation on windows

Use the certain design tools to generate the Rhapsody static data modules of the subsystems/devices. In addition to the interaction logic for the implementation module, it also automatically generates the communications modules between models and DDS communications network. After completing the system design module, the Windows executable programs can be directly compiled and run immediately to verify the results of the system design, as well as establishing the simulation of communications between the modules and the joint simulation of multiple models.

3) Real-time digital simulation

After the Windows digital simulation, based on platform independence of the models and DDS middleware, the object file Linux platform can be compiled and generated. Download it to the real-time Linux operation system can verify the sequence and performance of subsystems/devices.

4) Hardware-in-loop simulation

Based on the full digital real-time simulation, the HILS (hardware-in-loop simulation) uses the certain simulation tools to achieve the binding of the modules ICD with the board and the available channels of the real-time simulation computer graphically [10]. Use real cards (429, 422, 1553B) to form the avionics simulation network can simulate and verify the functionality and performance of the model in the real bus interface environment.

C. System Implementation

The system implementation stage is the based on the modules of design and multiple iterations. Use the bottom of the real avionics devices to realize the card drivers and the module supporting programs. Instead of the automatically generated DDS simulation network, the replaced module code will be compiled and downloaded to the embedded target machine, forming the principle prototype.

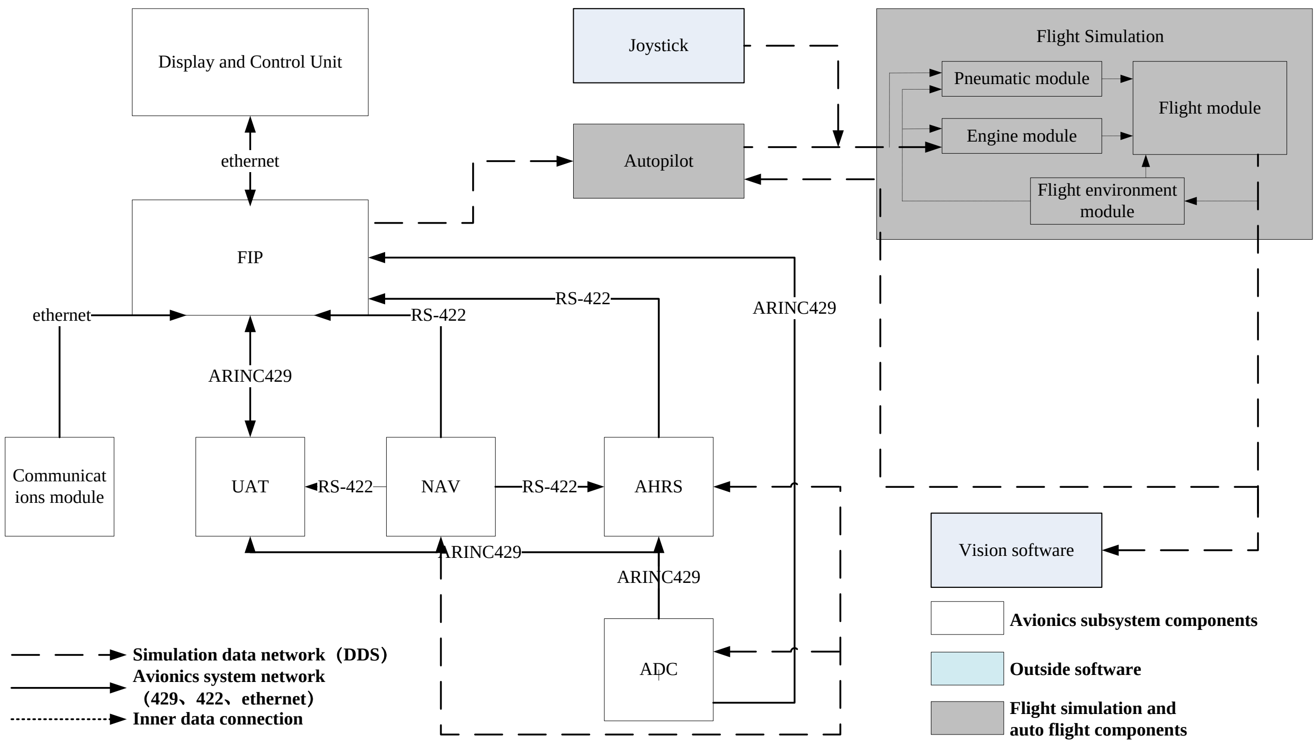

Fig. 3. Digital prototype architecture of general aviation avionics.

The principle prototype of the subsystem/devices can access to the HILS network. It will operate with the other simulation modules in the avionics network to complete subsystems/devices testing instead of the real-time simulation modules.

D. System Integration and Test

On the basis of HILS environment, the subsystems' untested devices can be accessed by the wiring layout system for the incremental and iterative system integration instead of the corresponding real-time simulation modules. Through the cross-linking experiments, the system-level problems can be located for the system integration.

IV. Application

The integration development platform and application of the avionics system based on the model-driven is already applied in the national 863 subject "The general design, integration, testing and validation of the high integrated avionics system of the general aviation". It is based on this platform to complete the system ICD design, DD design, POP design of the display control unit , digital simulation, HILS and the system integration; develop the digital prototype of general aviation avionics system including the display control unit, FIP (flight information processor), NAV (navigation), UAT (universal access transceiver), communications module, ADC (air data computer) and AHRS (attitude and heading references system) through the model-based design approach; combine with the flight simulation, visual software, joystick, wiring layout system, specific simulation/acquisition and monitoring tools to build the system environment of HILS and integration testing, as well as completing the lab validation of the project before the car testing and trial flight. The digital prototype architecture of general aviation avionics is shown by Fig. 3.

The digital prototype of general aviation avionics is composed by following aspects:

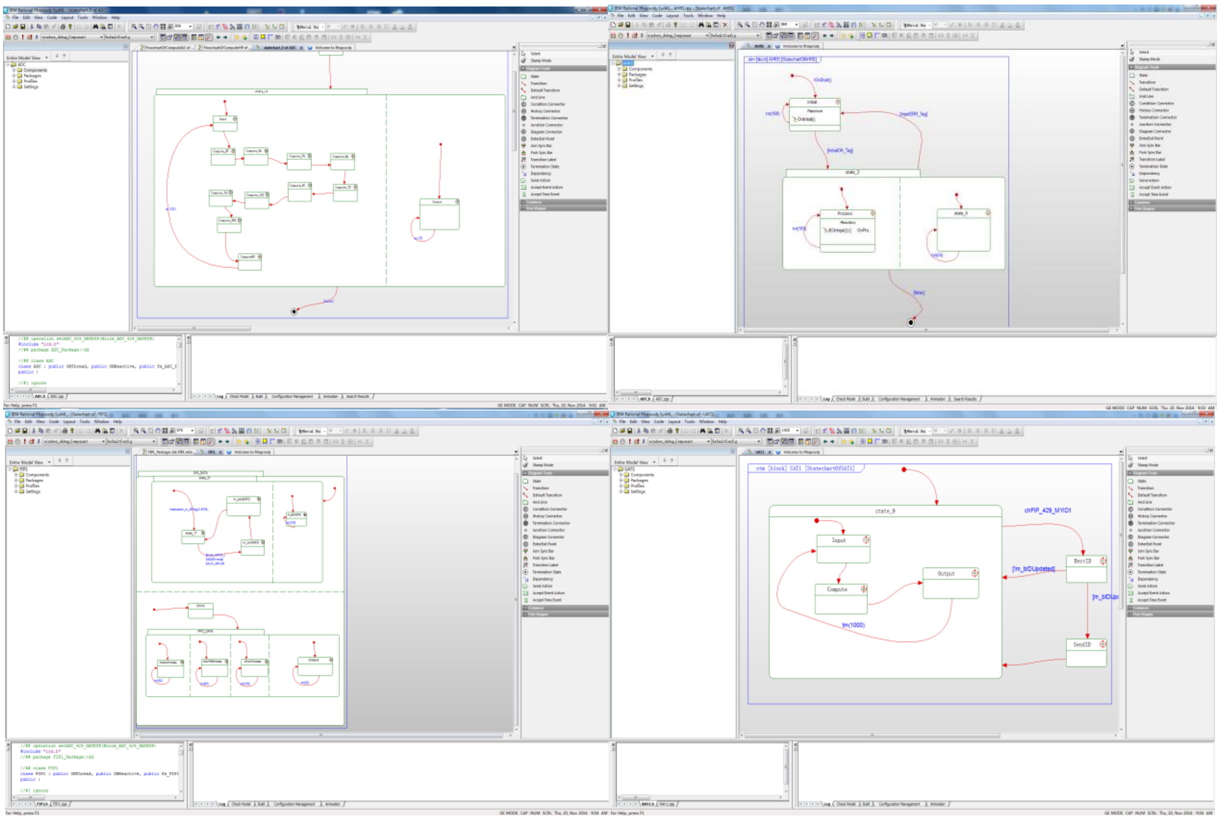

Fig. 4. Design interfaces of avionics subsystems modules.

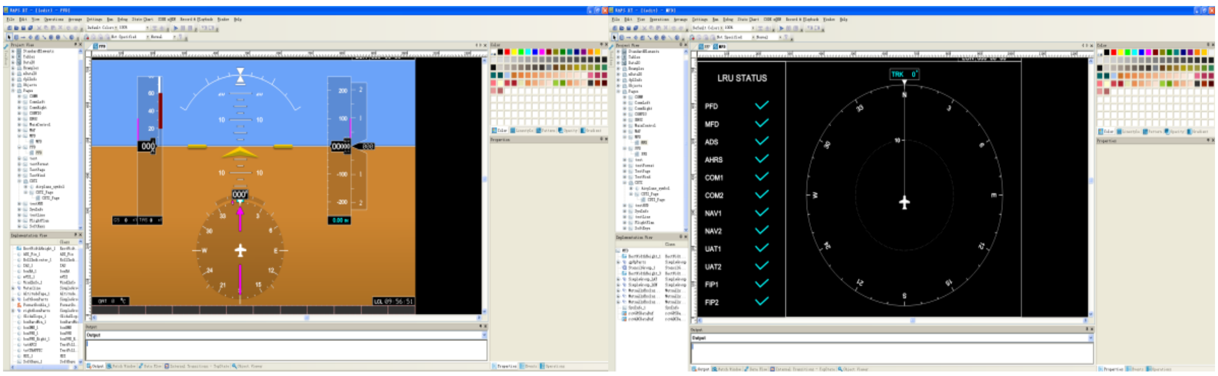

Fig. 5. Interfaces of the display and control unit.

A. Avionics System Modules

Avionics system contains the FIP model, NAV module, UAV model, ADC model and AHRS model. Use the certain design tools to export Rhapsody modules framework of the subsystems, which includes the interaction logic module consistent with ICD and the communications modules with the DDS simulation network. All the business logic of the subsystems is designed by the UML flow diagram and states diagram. The model design interface is shown in Fig. 4.

B. Display and Control Unit

The display and control unit contains the PFD (Primary Function Display) and MFD (Multi-Function Display). PFD is used to indicate the attitude, airspeed, altitude, vertical speed, horizontal and other information of the aircraft. MFD used to indicate the air traffic, navigation station, communications station, equipments status and other information of the aircraft. The display and control software uses VAPS XT to develop, of which the design interfaces are shown in Fig. 5.

C. Flight Simulation Model

According to the controlled quantity of the aircraft rudder information and engine, the flight simulation module outputs the status information of the aircraft, including the aircraft dynamics model, engine model, aircraft rigid body kinematic model and flight environment model.

The flight simulation module uses the same design method as the avionics subsystem modules, which adds the specific calculation algorithm on the Rhapsody model framework including the DDS communications simulation module.

D. Joystick Software

The joystick software collects the input data through the USB interface HOTAS flight joystick. And it sends the corresponding control instructions to the flight simulation module. The data structure of the transmission joystick instructions is shown by Table I.

TABLE I. THE DATA STRUCTURE OF THE TRANSMISSION JOYSTICK INSTRUCTIONS

```
typedef struct _StickParseData{
  unsigned int m_uiHori;//Horizon
  unsigned int m_uiVert;//Verticality
  unsigned int m_uiRudder;//Yaw
  unsigned int m_uiAcc;//Accelerator
  bool m_bA;//A key
  bool m_bB;//B key
  bool m_bC;//C key
  bool m_bD;//D key
  bool m_bFire;//Fire key
  byte m_byMode;//Operation mode key
}StickParseData;
```

E. Vision Software

The vision software uses FlightGear to receive real-time status information of flight simulation modules and then displays the status of the aircraft. The interface of the FlightGear is shown by Fig. 6.

V. CONCLUSION

The integration development platform and application of the avionics system based on the model-driven is already applied and verified in the national 863 subject. This platform is based on the V model development process and fully learned from the foreign advanced design tools and concepts. It mainly designs and realizes the smooth transition between the design stages, design and simulation, design and integration testing stage. The integration of research and development environment, which is based on models to support the whole development process, contains the model-driven design, simulation, implementation, integration and testing. Adopt the documents/code as output and using the various design tools will cause the problems, such as the heavy maintenance work, difficulties of the results reuse, poor link of all the design stages, high risk and so on. This paper proposed the method to solve the above problems and could better achieve to the requirements of the current avionics system development.

Fig. 6. FlightGear software.

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