RESEARCH ON DESKTOP VIRTUAL INTEGRATION AND VERIFICATION OF CIVIL AIRCRAFT

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Abstract

The paper describes the implementation process and application plan of desktop virtual integration and verification based on actual aircraft design requirement. Firstly, it analyzes the requirement and challenge for the whole aircraft onboard system virtual integration, then illustrates the concrete methodology and scheme for practical implementation to achieve the successful integration of three hierarchy fidelity models and exchange of data. It also describes the critical factors on virtual integration, such as simulation and modeling specification, tool chain choice. The paper also proposes the method to promote the credibility of virtual test, providing an extra means of compliance for airworthiness.

Nomenclature

AFHA: Aircraft Function Hazard Analysis
Function Model: Model or library developed by function simulation and modeling tool based on aircraft operating scenario and function definition, such as Rhapsody, EA, Capella
DDS: Data Definition Specification
EICD: Electrical Interface Control Document
FHA: Function Hazard Analysis
FICD: Function Interface Control Document
FMI: Functional Mock-up Interface, connecting and integrating all kinds of physical models
FRD: Function Requirement Document
Logic Model: Model or library developed by architecture simulation and modeling tool based on architecture trade study, such as C++, Simulink, SCADE
LRU: Line Replaceable Unit
MICD: Mechanical Interface Control Document
MIT: Mapping Integration Test
MRD: Model Requirement Document
MTD: Model Test Document
MoICD: Model Interface Control Document
MTS: Model Test Specification
MV&VP: Model Validation & Verification Plan
SRD: System Requirement Document
SRS: System Requirement Specification
OEM: Original Equipment Manufacture
Physical model: Model or library developed by specialized simulation and modeling tool based on virtual integration and energy optimization, such as AMEsim, Saber, Dymola
PS: Product Specification
PSSA: Preliminary System Safety Analysis
SDN: Shared Data Network based UDP communication protocol, connecting and integrating all kinds of logic models
S&M：Simulation and Modeling
SSM: System Simulation Module
Virtual Integration: The virtual integration discusses in the paper is mainly aimed at integrating the whole aircraft onboard system simulation model, used for requirement validation and integration verification at aircraft &system level during the lifecycle of civil aircraft
V&V: Validation and Verification

1 Introduction

The modern civil aircraft is more integrated, complicated and intelligent, the traditional document based design and physical test based verification method cannot support current new complex aircraft development effectively any more. It will result in schedule delay, cost overrun, even project failure in the worst case [1-3].

Desktop virtual integration is an emerging and feasible method to solve the above problem, it can be quick prototype at different design phase by modular mask, virtual integration and simulated flight. The integrated aircraft model covering multi-discipline onboard system supports lifecycle aircraft and system level requirement validation and verification [4-6].

2 Target and Challenge

2.1 Target

The virtual integration has three main targets:

- The virtual integration to support concurrent engineering of aircraft design, integration and verification, promoting the design maturity, optimizing the design architecture, discovering the design error early and reducing physical test load by iteration.
- The virtual integration to support later large scale physical integration by providing simulation model, test case, test scenario and criterion.
- The virtual integration to support virtual test and certificate of aircraft.

2.2 Challenge

- The first challenge of aircraft virtual integration is multi-discipline couple simulation, including aerodynamic, mechanical, hydraulic, electrical, control, etc.
- The second challenge is the development and obtainment of simulation model, it will involves almost all the onboard system suppliers and OEM design department.
- Furthermore, the integration, check and management of lots of different fidelity model is also a big challenge.

3 Methodology and Scheme

3.1 Integration Scope Definition

The desktop virtual integration is primarily focus on onboard system function and performance simulation, and also considering physical structure simulation as necessary, it is neither fluid nor electro-magnetic simulation. It can be called virtual iron bird or virtual integration aircraft based on the integrated systems as shown in Fig.1.

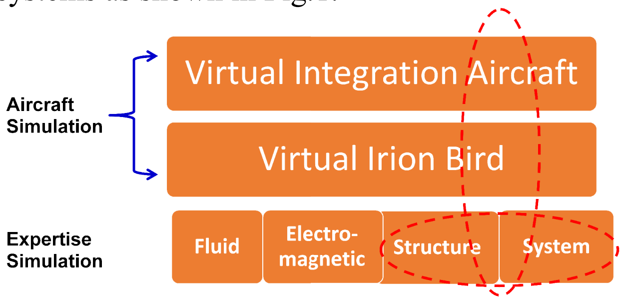

Fig. 1 Virtual Integration Scope

3.2 The Hierarchy of Simulation Model

According to the development process of aircraft and real engineering implementation requirement, the simulation model is divided into function model, logic model, physical model separately based on fidelity, complexity and design phase.

- Function model is used for validation and verification of FRD, FICD, AFHA, PASA in the feasibility and concept phase;
- Logic model is used for validation and verification of SRD, EICD, FHA, PSSA in the preliminary design phase;
- Physical model is used for validation and verification of SRS, PS, MICD in the detail design phase.

Meanwhile, the desktop virtual integrated environment for different hierarchy model is used to support key review and transition of development phase.

3.3 The Architecture of Integration Platform

3.3.1 Platform

In order to find the design error earlier and promote the aircraft development efficiency and mature, we plan two platforms for the aircraft virtual integration test as shown in Fig.2. The article is focus on the first desktop simulator and it will become engineering simulator along with the development process gradually which is supporting pilot-in-loop and hardware-in-loop test.

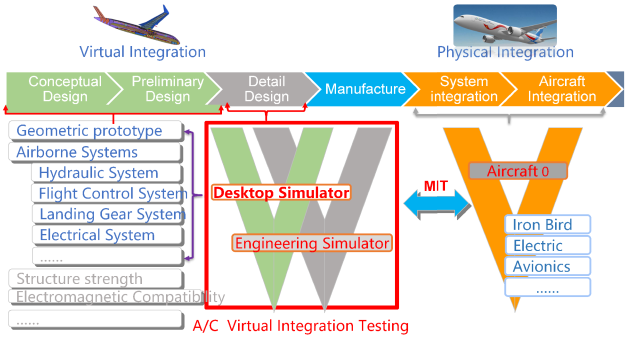

Fig. 2 Virtual Integration Platform

3.3.2 Architecture

The overall architecture of the desktop simulation is based on client-server distributed control system as shown in Fig.3 [7-9]. The client computer is used to development, integration and test simulation model in non-real time environment, the server computer is used to run the code generated from the client simulation model in real-time operating system.

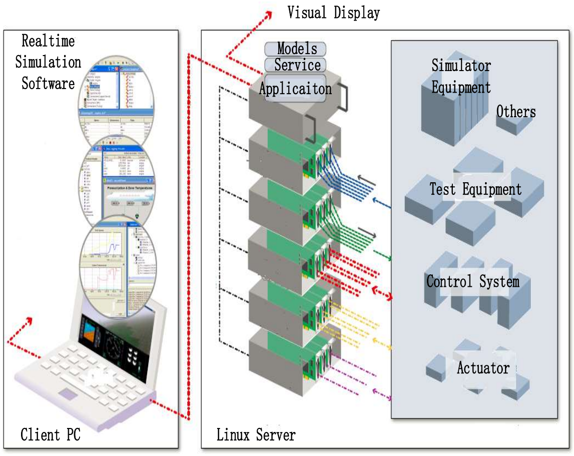

Fig. 3 Overall Platform Architecture

3.4 The Integration of Simulation Model

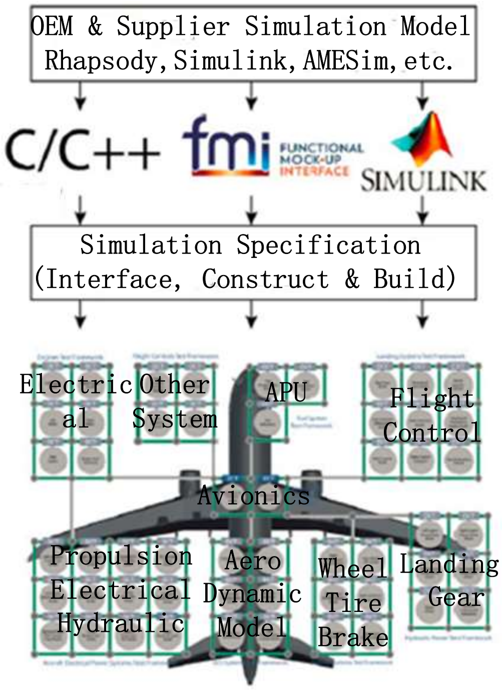

Fig.4 Simulation Model Integration Method

For simulation models, some of them are developed by OEM and others are developed by suppliers, there are two key aspects for successful integration of so many different simulation models covering almost all aircraft onboard system [10-11]. The first one is the unified, detail simulation model specification and the second one is the simulation platform architecture. Just as shown in the Fig.4, The simulation model after test will be integrated into the simulation environment by simulation model interface layer. The simulation model interface layer can be compatible with the C/C++, Simulink and FMI, supporting common simulation tool, such as rhapsody, dymola, Simulink, AMESim, Saber, etc.

3.5 Test Case for Requirement Verification

The Fig.5 is a requirement verification test case conducting on the desktop simulation platform, the input is the aircraft and system requirement, then developing the test scenario and test case for each requirement and doing the verification test on desktop simulation platform. After finishing the test, then feedback the verification conclusion to the requirement definition team for requirement iteration and transform the test scenario, procedure, criterion to the aircraft level bench team for future physical integration test.

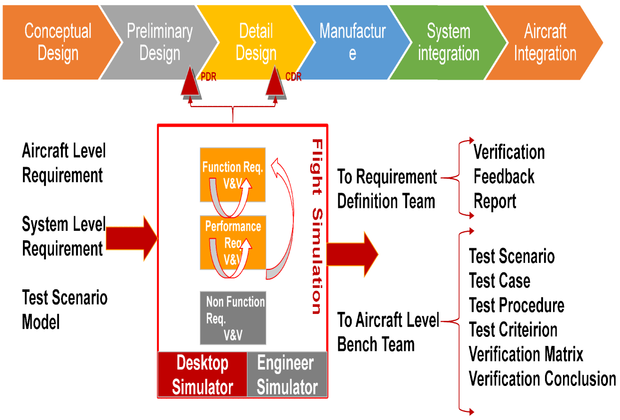

Fig. 5 Requirement Verification Process

4 S&M Specification

In order to promote the effectiveness and efficiency of model development, test, integration and application, it is necessary to define the unified simulation modeling specification in the very early stage, including model function, performance, development tool, simulation environment, configuration, test, etc. to guide the simulation model development [12-13].

We take the simulation model as the simulation "LRU" comparing with the aircraft onboard system. Just as the Fig.6 shown, we define several specifications along with the aircraft development process, including the MV&VP, MTS, MRD, MTD, MoICD, etc. We will also build connection between the OEM model development process and suppliers'.

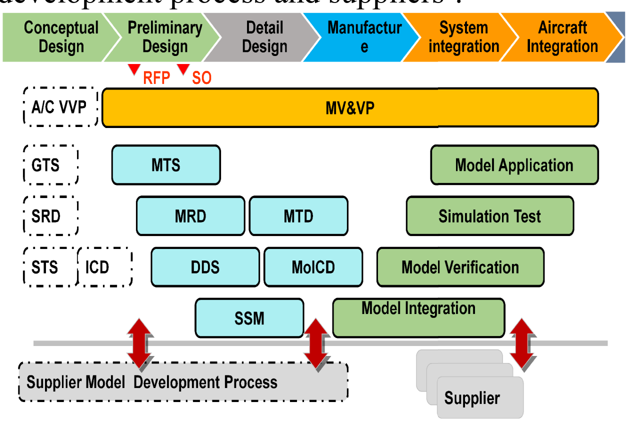

Fig. 6 S&M Specification

5 S&M Tool Chain

It needs to development and integrate various fidelity system simulation models along with different design phase. In order to better implement desktop virtual integration and play an important role in aircraft design lifecycle, complete the virtual integration target, the choice of modeling tool shall consider based on the aircraft design tasks and seamless tool chain integration, then facilitating the transfer of de-sign data [14].

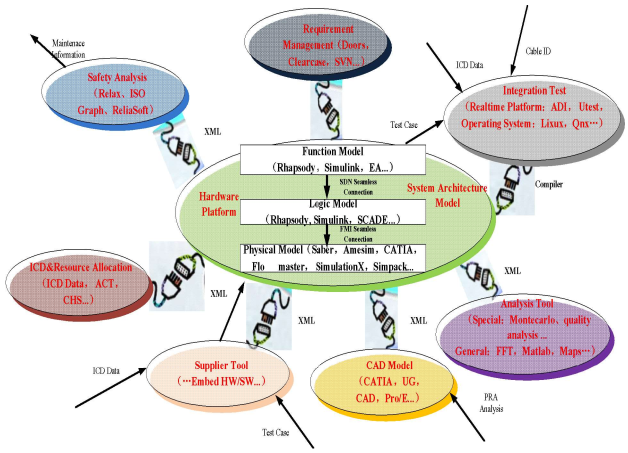

Fig. 7 S&M Tool Choice Guideline

Just as the Fig.7 shown, we plan to choose the simulation tool based on engineering requirement and experience, considering the tool maturity as well, it makes much easier for integration of different simulation tools using along the aircraft development process.

6 Validation and Verification of the Simulation Environment

Flight test is the most important method to show compliance to the authority currently, but future compliance test will be transferred to desktop simulation more and more with the development of S&M technology. EASA takes the opinion that virtual integration test is the tendency and it may be provide an extra method to show compliance[16-18].

Simulation fidelity and creditability validation is necessary process for virtual test. We will do the model and environment validation and verification test in several design phases and let the simulation fidelity more and more creditable. For our desktop simulation, we will verify the simulation model and environment by reliable data source from engineering simulator, bench test and flight test step by step, the detail V&V process is as shown in Fig.8.

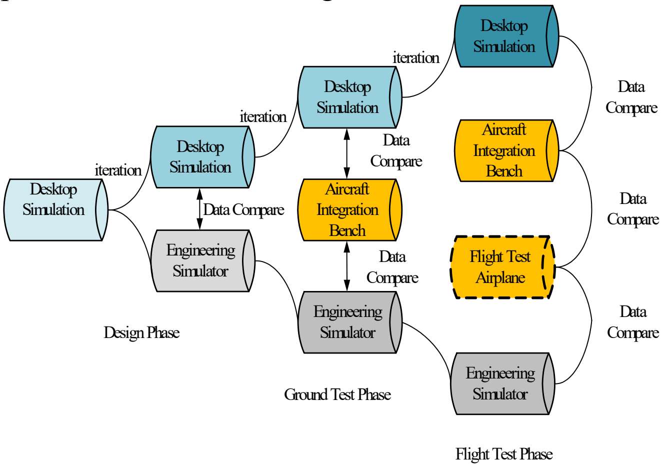

Fig. 8 Virtual Simulation V&V Process

6 Conclusion

The paper proposes a virtual integration method along with the development process of civil aircraft, it solves the real problems encountering on the engineering implementation and find design error earlier by systematic plan, iteration process and efficient tools. Furthermore, it is a good practice for concurrent engineering and MBSE, it makes the design process more mature and creditable, meanwhile, promoting the efficiency and saving cost.

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