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Integrated Cockpit Simulation Design for Civil Aircraft Alerting System

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***Abstract*—The necessary for integrated systems development comes from complexity of the system. The cross-linking among the sub-systems of the aircraft attributes to the difficulty of recording and indicating system design, especially alerting system. This paper presents a practical simulation design solution for the sophisticated civil aircraft alerting system pointedly. The data structure of alerting messages with attribute has been demonstrated as the design schema firstly. Then, the trigger of the alerting messages, including status of aircraft sub-systems, external environment impact, human factor aspect, and logic judgement have been then studied and discussed. The priority and inhibition mechanism are two significant aspects in the field of logic dependency research. Compared to the traditional design methodology, this proposal owns the advantages of flexibility, re-usability, modulation, and portability. As a case study, the implementation of the proposed design approach is demonstrated on an experimental cockpit platform, namely desktop-PC based flight deck HMI simulator finally.**

Keywords—data structure; integrated cockpit design; modelling and simulation; software engineering; alerting system

I. INTRODUCTION

As the complexity of aircraft system integration increases, the interaction between pilot and flight deck plays a crucial role in the flight crew operation. Issues with human-machine interaction has been evidenced as one of the most dominated causes behind the aeroplane crashes. The reasonable design of the Human Machine Interaction (HMI) alerting system can identify the possibility of pilot's abnormal action that may lead to a pilot-cockpit interaction related incident (Neha, et al., 2012). Additionally, the terrible influence from the internal and external environment, such as low visibility, turbulence, smoke, can be predicted through well-design alerting system (Neha, et al., 2012).

With the drastic advancement in computer and software technologies, the aviation industry is gradually moving towards the use of Integrated Modular Avionics (IMA) for civil transport aircraft, potentially leading to multiple avionics functions housed in each hardware platform (Cody Harrison Fleming, 2014) & (Leanna K. Rierson, 2004). The same like the aviation system, because of the multiply systems related data structure and complex inhibition mechanism the modular and integrated HMI alerting system has become the research frontiers of cockpit simulation for next generation aircraft.

The benefits of traditional aircraft alerting system from a start-up in the preliminary phases to the first delivery in the aircraft development process could be questioned. It seems reasonable that in some cases, that the traditional alerting system design equipped with the aircraft currently is able to guarantee the normal and abnormal flight cycle. Nevertheless, the following are the other aspects, which need to be considered: 1) Recording and indicating system should be designed and evolved with the system development process. More prototypes in the development cycle may increase costs substantially.2) Concluding a development process by modifying something that could have impacted the maturity of the product's release and increases the risk of detecting defects later. 3) Finding problems during the conceptual phase is too abstract and could not potentially clarify the final certification date and, as a consequence, the test bed for temporary aircraft altering system is required. 4) The conflicting alert information to be transmitted by different alerting systems is needed to be modeled to minimize the potential and impact of alerting conflicts or dissonance (Kuchar & Song, 2001). To answer the listed questions, this paper proposes an integrated simulation design methodology for civil aircraft alerting system.

II. CIVIL AIRCRAFT ALERTING SYSTEM

The alarm system on modern civil aircraft usually uses visual, auditory and tactile method to locate the fault of the aircraft system or components in time to improve the safety of the flight (G. BOUCEK, et al., 1981). The warning system should be able to attract the attention of the flight crew members, indicate the root of the problem, and provide corrective guidance as soon as possible.

The visual alarm mainly includes the following alarm modes: master warning or caution warning, CAS information and fault flag. The master warning or caution produces visual instructions for attention on system failure or abnormal operation of the device. It is usually classified as different priorities with color according to the emergency degree (Yang & Kuchar, 1997), such as red or amber warning instructions. The priority of the alarm message is also related to the required response speed of flight crew member, and the same alarm message may be defined as different priorities in the distinguished flight stages and aircraft configurations. CAS information provides some clear and accurate information in the form of text information for the crew member. The fault flag is used to indicate the failure of a certain parameter. The auditory alarm consists mainly of a specific sound, fire alarm or speeches, which should be notable and not harsh in generating attention, such as a homophonic sound, voice alarm, and specially defined voice (tone) (G. BOUCEK, et al., 1981). The speech alarm is used to inform the characteristics of the flight related alarm, and the speech alarm information should be distinctly different from the normal radio communication voice, such as the use of unique synthetic speech (G. BOUCEK, et al., 1981). The tactile alarm provides urgent message through physical touch, feedback force or vibration. Modern civil aircraft usually does not use tactile warning alone, but combines tactile and acoustic alarm together.

At a special flight stage, an alarm is manually or automatically inhibited by the system when the alarm is not needed or not. The alarm inhibition can be used to prevent the emergence of multiple alerts and cause confusion. The purpose is to prevent the attention of the dispersing unit and cause additional harm. The alarm can be inhibited in the following cases: A) the alarm will distract the attention of the flight crew members in the dangerous situations; B) the warning caused confusion; C) the alarm provides the aircraft status information that is not needed (Kuchar, 1996).

The alarm design for civil aircraft should be able to inform the crew at the first time when the alarm occurs, help the crew to locate the fault position and take corresponding measures (WANKE & R. HANSMAN, 1991). In order to achieve this goal, the alarm of civil aircraft is usually combined with different alarm elements. The alarm elements used on civil aircraft usually include master warning/master caution, CAS information, voice alarm (tone), tactile information, fault flag, etc. In this paper, the focus of cockpit simulation design emphasizes on the alert formality, message data structure with attribute, logic dependency, and influence from flight stage on the inhibition mechanism, and a desktop-PC based flight deck HMI simulator has been illustrated to act as the test bed. Compared with the real cockpit working environment, the auditory effect, tactical alerting, hard real-time requirement have been little considered in this work.

III. INTEGRATED SIMULATION DESIGN

As the second section described, the alarm system equipped with the civil aircraft can be classified as text message and aural message. Each message owns its unique ID, reference number, priority and type. The text message definition contains also a short description and display allocation information. As Fig. 1 shows, the logic blocks link to n-messages according to their priority and inhibit law. The inhibit law consist of priority mechanism and flight phase inhibit. Regarding the priority mechanism, the alerting message can be prioritized as different levels, such as caution, advisory, status, information, etc (VEITENGRUBER, 1977). The most urgent alerting message is to be sorted as the first class with red or amber color and displayed in the obvious position in the screen and the secondary urgent alerting message follows it with other different colors. At some special flight phase, an alarm with the attribute “Umbrella Message” can be automatically inhibited by another alarm when it is not needed or not. In the similar condition, the alert message with the attribute “Collector Message” can also dominate another. That is the mechanism of the flight phase inhibition. As the diagram in Fig. 1 displays, the message classification and the flight phase inhibition with the “Umbrella” and “Collector” attributes contribute to the statement of the alert message logic. The aural message occupies also the similar attributes and logic statement.

In addition, the pilot action, including normal and abnormal operation has influence on the alerting system, which can also be considered as the trigger of the text or aural alert message emergence. The external input can trigger and eliminate the alert message, which brings the aircraft system back to the normal status. That is our basic data structure of alerting system for the civil aircraft in this work and will be used in the experimental flight test environment.

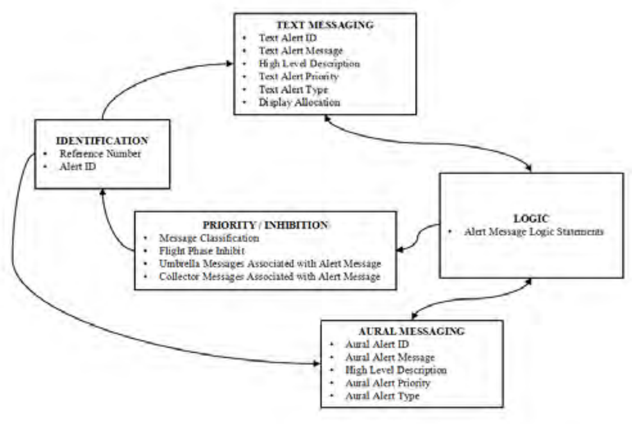

FIGURE I. DATA STRUCTURE AND DEPENDENCY OF ALERTING SYSTEM FOR CIVIL AIRCRAFT

A. *Desktop-PC based Flight Deck HMI Bench*

In order to demonstrate the proposed integrated simulation design with civil aircraft alerting system, an experimental test bed is set up. A desktop-PC based flight deck HMI bench has been equipped to provide a suitable proof-of-concept facility.

The desktop-PC based flight deck HMI simulator is a networked cluster of high-end commercial off the shelf (COTS) computers as shown in Fig. 2, which can be used to establish the actual needs of the pilot in the early design phase. This facility will take VAPS XT 4.1.1 as development tool of human-computer interface, build logic diagram through MATLAB/SIMULINK R2011b explicitly cooperating with the physical control parts such as the side bar and pedal. The flight scene from the Prepare3D v4.1 developed by the Lockheed Martin Company makes the whole system as highly integrated desktop simulation platform, which helps pilot to integrate with the external environment. The platform can restore the test environment for testing and validating the reason-ability of cockpit HMI design, and provide solid data support for the alerting system research and development.

FIGURE II. A OVERVIEW OF DESKTOP-PC BASED FLIGHT DECK HMI SIMULATOR

Additionally, the touch control technology can help the aerospace engineers to carry out basic research and experiment with the new generation of aeronautical HMI design in an experimental environment. The key features of the desktop simulation platform provided are as follows:

- It is a highly integrated professional platform environment with modularity attribute. The display and control logic adopts modularization design concept, which can quickly replace the display HIM logic of control panel.
- The database provides abundant display elements and controller library for various models, and can quickly reconstruct the display interface.
- Communication system supports the unified UDP protocol, which can seamlessly achieve interface replacement and iteration.
- Through the efficient MySQL database technology and data acquisition system, the desktop-PC based flight deck HMI simulator can support the acquisition of a large number of flight personnel operating data and graphic processing data.
- The integrated control interface is convenient for user to operate the platform with one key start, interface transmission, scene setting, data monitoring and so on.

The platform is safe, reliable, fast, easy to maintain, and is suitable for evaluating the human-computer interaction aspect of wide body airliner or similar aircraft and the function validation for recording and indicating system, especially altering mechanism.

B. Design Prototype for Alerting System

The integrated simulation design methodology is able to simulate the aircraft alerting systems in the case of pilot's abnormal operation and external environment. The desktop-PC based flight deck HMI bench presents a more complete and realistic aircraft model, which includes engine indication and crew alerting system (EICAS). This software model contains the mathematical and logic modeling to make the aircraft behave likes the generic flight vehicle. Matlab/Simulink is the software development platform.

The altering system design prototype can be programmed with the code or embedded as a Matlab/Simulink module integrated in the desktop-PC based simulator (as shown in Fig. 3). The pseudo code is a kind of design prototype for civil aircraft alerting system with the integrated cockpit simulation. The EICAS content on the test bed platform can be replaced or inhibited by this new designed alerting model.

```
Start();
        Initiate();   // initial parameter in workspace and simulink
        timer();      // call the alert system function repeated
        UDP module; // receive server warning string, e.g. "FUEL 456". FUEL is type and 456 is alert ID
        phase();      // identify different flight phases
        system classification (switch case);          // identify different alert type
        Case 1: Fuel System
        read .xls sheet including alert content, type, umbrella, collector, inhibit, etc.
        Alert.classification(); // identify different alert ID according to priority.
        Case 2: Hyd System
        read .xls sheet including alert content, type, umbrella, collector, inhibit, etc.
        Alert.classification(); // identify different alert ID according to priority.
        ... ...
        Case n: XXX System
        read .xls sheet including alert content, type, umbrella, collector, inhibit, etc.
        Alert.classification(); // identify different alert ID according to priority.

        alert package;          // package the alert messages with priority, flight phase, inhibit, etc.
        alert.pack()
        ... ...
        alert.pack()
        alert.sort() // Sort the alert messages according to priority and flight phase
```

FIGURE III. INTEGRATED COCKPIT SIMULATION LOGIC FOR CIVIL AIRCRAFT ALERTING SYSTEM (PSEUDO CODE)

The integrated and modular alerting system benefits the cockpit HMI design, especially in the field of the aircraft abnormal condition. The data structure of the alerting system has been proven as the realistic proposal with the pseudo code in Fig.

3 after experiment on the desktop-PC based flight deck HMI bench. With the data structure stated in the last section the other cockpit simulation logic can be realized with C code or other programming languages on the test bench.

IV. DISCUSSION AND CONCLUSION

This manuscript proposed an efficient approach to conducting the integrated simulation design for alerting system. The background and the state of art has been introduced and acts as the foundation of the alerting simulation design in this paper, including the dependency logic, correction and consistency of alerting message, and influence on the inhibition from flight phases and priority. The data structure and the program of the alerting system serve as the methodology of the integrated simulation design. The desktop-PC based flight deck HMI simulator can be used as the test bed for integrated alerting simulation design methodology.

Compared with the real flight deck interior working environment, the auditory effect under the pilot working condition, tactical alerting message, and hard real-time requirement is not the key point of this work. Regarding to the cost and efficiency aspect, the data model was adequate to support the alerting system design and research and it has also been applied as the design prototype at the preliminary and final validation design phase of V&V (verification and validation) development process.

The results showed that the pilot and human factor experts are satisfied with this integrated alerting simulation design in the process of cockpit evaluation and assessment.

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According to the confidential disclosure agreement with Shanghai Aircraft Design and Research Institute (SADRI), the figure of desktop-PC based flight deck HMI simulator published in this paper have obfuscated.

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