Research on modernization directions of the human-machine interface of flight management system for future civil aircrafts

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Abstract. The article proposed the description of the developed human-machine interface of the flight management system for future civil aircraft. The directions of development, existing solutions and also technical documentation requirements for this type of interface are analyzed. A number of solutions are proposed that implement new ways of presenting information and provide for intuitive and reliable interaction with a crew.

1. Introduction
For more than a half of century of passenger aircraft avionics evolution a lot of different architectural solutions, technologies and concepts of cockpit organization have appeared. The appearance of the integrated modular avionics (IMA) architecture [1, 2], the glass cockpit concept and then the dark cockpit led to a wide spread of screen indicators, which occupies an increasing part of the working field of the crew with the appearance of each new aircraft.

Nowadays, the main task in building the philosophy of the cabin is the task of convenient and reliable presentation of a large amount of information which is necessary for the crew for timely and error-free decision-making on aircraft control. The constantly-increasing requirements for the human factor in the analysis of functional hazards suggest the need for careful study of human-machine interfaces (HMI) throughout the cockpit, and, in particular, HMI of cockpit display system [3].

The concept of the dark cockpit, the most actual for today, involves the need to attract the attention of a crew only on the significant elements in the current operational environment in the field of view, without attention to the secondary information.

The increase of the number, sizes and resolution of digital screens in the cockpit led to the need to rethink and redesign of cockpit HMI, and, in particular, the most functionally loaded part of it – HMI of flight management system (HMI FMS) [4].

Due to the proliferation of the IMA architecture and wide-format indicators, as well as the growth of the FMS system functionality, the system developers were faced with the question of creating a fundamentally new FMI HMI that implements new ways of presenting information and provides intuitive and reliable interaction with a crew.

2. Analysis of HMI technical requirements
To simplify crew interaction with the FMS, the HMI should provide a number of ergonomic requirements for the data location on the information frame, as well as how the crew interacts with the frame elements. The main mandatory requirements for the cockpit displays and controls, which must be
provided by all modern aircrafts to obtain a type design certificate, are presented in all current airworthiness regulations, which for example is paragraph 25.1302 of the EASA document “Certification Specifications and Acceptable for Large Airplane” (CS-25) [5].

During the software developing process of the FMS HMI, it is necessary to follow the requirements of RTCA DO-178C / ED-12C [6].

The functional hazards of the FMS system assessment are based on the requirements of the document FAA AC 20-138D “Airworthiness Approval of Positioning and Navigation Systems” [7] and also in accordance with the recommendations of ARP4754A “Guidelines for the development of civil aviation aircraft and systems” [8].

Moreover during the developing process of perspective HMI, it is necessary to take into account the global trend to switch to touch screens instead of keyboards and pointing devices. It is advisable to assume the possibility of using both conventional and touch screen to simplify the interaction of the crew with the FMS.

3. Main directions of modernization
As a result of the analysis of existing interfaces and the required functionality, the following directions of modernization were identified and should be considered during developing phase:

- Implementation of the strict zonality principle;
- Sections navigation;
- Simplification of the pre-flight procedure;
- Interaction procedures with edit boxes.

The sketch of the FMS information frame structure that satisfies the desired requirements is presented in figure 1.

![Figure 1. Sketch of the FMS information frame structure](image)

3.1 Strict zonality principle
For quick navigation in the proposed interface, it is necessary to divide it into functional zones in order to quick search for necessary information. As a result of the analysis of various zonal divisions, the separation presented in figure 2 founded as the most intuitive.
On the proposed FMS HMI frame the data location is strictly defined that provide the same type of organization of the information location. The entire frame of the FMS HMI is divided into zones of permanent data and variable data zones.

![Zonal information distribution on the FMS frame](image)

**Figure 2.** Zonal information distribution on the FMS frame

### 3.2 Section navigation

In order to minimize the time spent, as well as to ensure a quick transition from any page of the frame to any other one, it is proposed to use a two-level navigation structure. The two-level structure provides transition between all pages for no more than two actions.

The first level is the main horizontal menu for navigating through sections; the second level is the tabs inside the section. The transition diagram for the sections pages of the FMS frame is presented in figure 3.
One of the main procedures requiring crew interaction with the HMI is the pre-flight procedure. To reduce the time spent on it, the following solutions are proposed for implementation:

- Buttons to go to the next logical page (provide a sequential passage through the obligatory pages for the flight plan formation on the pre-flight phase);
- Identifiers of the sufficiency and correctness of the entered data (show the correctness and existence of information in the required edit boxes of the relevant section).

As a result of the conducted research, it was found that the FMS HMI should be organized so that the task of pre-flight preparing for the flight is solved by going through the FMS pages in the setup wizard mode. The setup wizard mode provides quick sequential access and editing of the initial data that is necessary to start the flight plan formation. The scheme of passing through the sections of the FMS HMI frame is presented in figure 4.

In addition, to reduce the workload on crew when interacting with the interface, after filling all the necessary flight plan data, the entered data are checked for correctness automatically.

Sections in which a sufficient amount of necessary and correct data has been entered should be visually distinguished. For this purpose, color coding has been implemented in the section navigation menu zone, presented in table 1.

**Figure 3.** Transition diagram for the sections pages of the FMS HMI

### 3.3 Pre-flight procedure

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Figure 4. Scheme of passing through the sections of the FMS HMI frame

Table 1. Implemented color coding for the pre-flight procedure

| Menu section | Description |
|--------------|-------------|
| INDEX        | Selected FMS section |
|              | In the top right corner: marker of insufficient section filling with minimum required data |
| F-PLN        | In the top right corner: marker of the sufficiency and correctness of the entered data in the section |
| NAV          | In the event of warning messages: marker of the section, which the crew have to go to eliminate the cause of the message |
3.4 Crew interaction with edit boxes
In order to simplify the procedure for entering information, the following solutions are proposed:

- color coding introduction to distinguish information on the following types:
  - required or not required to enter information;
  - the value in the edit box is calculated automatically by the FMS or manually entered by the pilot.
- entry mask introduction;
- entered value checking for belonging to the physical range of the value.

Thus, when filling edit boxes, an indication of the format of the input data is provided. In the case of data entry by a crew, the manually entered value is checked for the physical range and correctness of the format with the corresponding indication to the crew. The elements of indication of erroneous data entry are presented in table 2.

### Table 2. Elements of indication of erroneous data entry

| Appearance of the item | Description                                      |
|------------------------|--------------------------------------------------|
| !                      | Invalid data entry format or insufficient input mask format. |
| -                      | The data entry format is correct, but not within the range of possible input. |

An example of the appearance of the data entry box with the predefined mask is shown in figure 5.

![Image of data entry box](image)

**Figure 5.** Appearance of the data entry box with the predefined mask

4. Conclusion
As a result of scientific and technical research, it was revealed that the existing FMS human-machine interfaces are overload and complicate interaction with it. To solve these problems, the main directions of modernization were defined, which must be taken into account during the development of the human-machine interface of the flight management system for perspective civil aircraft, as well as the requirements of the regulatory and technical documentation for this type of interface.

A number of solutions are proposed that implement new ways of presenting information and provide intuitive and reliable interaction with a crew.

The implementation of the proposed solutions allows reducing:

- time to prepare the aircraft for departure;
- crew learning time to work with the system;
- crew workload at all phases of flight.

References
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