Aircraft cockpit information field control methodology

E S Neretin\textsuperscript{1,2}, E M Lunev\textsuperscript{2}, N M Grigoriev\textsuperscript{3} and A S Ivanov\textsuperscript{1,2}

\textsuperscript{1} Moscow Aviation Institute (National Research University), 4, Volokolamske shosse, Moscow, 125993, Russia
\textsuperscript{2} Integration Center branch of IRKUT Corporation, 5, Aviatsionniy pereulok, Moscow, 125167, Russia
\textsuperscript{3} State Research Institute of Civil Aviation, 67, ul. Mikhalkovskaya, Moscow, 125438, Russia

E-mail: e.s.neretin@mai.ru

Abstract. The human factor remains one of the main reasons for occurrence of aviation accidents. At the same time, the number of avionics functions is increasing. That leads to increasing of displayed information quantity which has to be analyzed by the crew. In this regard, it is necessary to provide ways to control the displayed information without adding additional crew workload. Overview of existing solutions for cockpit information field control of modern civil aircraft is presented in this paper. These solutions do not provide a unified approach to information field control and can increase crew workload. To solve this problem, the cockpit information field control methodology using a rotary knob control panel is proposed. In this methodology unified approach is provided by introducing the special element (focus) for all levels of information control: the active display zone selection level, the page selection level and the selected page setting level including interaction with interactive elements. To evaluate the proposed methodology the aircraft indication system simulator was developed. Results of the test session with crew members showed that the proposed methodology allows to decrease crew workload and improve cockpit ergonomics.

1. Introduction

Despite the increased automation of aircraft control, one of the main causes of aircraft accidents is the human factor. Different reasons can lead to wrong actions, such as: excessive confidence in automation, its non-obvious behavior, lack of crew awareness, and others. Also, during the flight, the crew workload may increase to the level when crew members feel stressed. This can lead to wrong decisions \cite{1, 2}.

When cockpits are developed, in order to reduce the crew workload, much attention is paid to creating the intuitive representation of the large information amount required during a flight and optimizing the pilot’s actions quantity.

Widescreen digital indicators are the main means of displaying information on modern aircraft. With a large quantity of different control panels, they form the information-control field of the cockpit, which is one of the most functionally loaded parts of the aircraft.

Displayed information can be configured in various ways depending on the flight phase and performed tasks. The configuration is carried out using a big number of different devices—buttons, knobs, trackballs, etc., which are located in different parts of the cockpit. There is not a unified approach to the displayed elements management. It leads to the crew workload increasing.
The aircraft cockpit information field control methodology using a rotary knob control panel was proposed. This solution allows reducing the crew workload due to the implementation of a unified approach for whole display system elements controlling.

2. Existing solutions analysis

This section presents the analysis results of the modern civil aircraft cockpits: Airbus A350, Airbus A220, Boeing 787, and MC-21.

The typical structure of the mentioned systems is as follows. In the normal configuration, outer indicators display pages called the Primary Flight Display (PFD) and the Horizontal Situation Indicator (HSI). Other indicators are multi-functional, which means that displayed information can be configured in different ways. Necessary information for the crew is contained in the following pages [3–7]:

- synoptic (SYN), which display information about aircraft systems state. Usually, this is: a flight control system, an electrical system, a hydraulic system, an air management system, a fuel system, a doors system, and a brake control system;
- navigation display (ND);
- flight management system virtual control panel (FMS VCP);
- radio management system virtual control panel (RMS VCP);
- frame with summary information of aircraft systems status (STATUS);
- checklists (CHKL);
- engine and Warning Display (EWD), which displays the engines parameters and a zone with text messages about failures and recommendations for the crew actions.

The Airbus A350 cockpit information field is managed by the following controls panels, which is shown in figure 1 [4]:

![Airbus A350 cockpit control panels.](image)

**Figure 1.** Airbus A350 cockpit control panels.
• Electronic Centralized Aircraft Monitoring Control Panel (ECAM CP), used for accessing to synoptic frames, navigating through the configuration menu, managing messages, etc. and located at the pedestal;
• Keyboard and Cursor Control Unit (KCCU), used for interacting with interactive elements and located at pedestal;
• Electronic Flight Instruments System Control Panel (EFIS CP), used for PFD and ND controlling and located at the top of the instrument panel.

The Airbus A220 cockpit information field is managed by the following controls panels, which is shown in figure 2 [5]:
• Multifunctional Keyboard Panel (MKP), used for entering of text information, controlling displayed information configuration, which is located at the pedestal;
• Cursor Control Panel (CCP), used for dealing with interactive elements and located at the pedestal;
• Control Tuning Panel (CTP), used for PFD and ND controlling and radio equipment management, which is located at the top of the instrument panel.

![Airbus A220 cockpit control panels.](image)

**Figure 2.** Airbus A 220 cockpit control panels.

The Boeing 787 cockpit information field is managed by the following controls panels, which is shown in figure 3 [6]:

• Electronic Flight Information System Control Panel (EFIS CP), used for PFD and ND controlling, which is located at the instrument panel;
• Multifunctional Keypad (MK), used for entering text information, lower indicator information configuration management, cursor controlling, etc., which is located at the pedestal;
• Display Select Panel (DSP), used for pages reconfiguration on upper indicators and located at the instrumentation panel;
• Cursor Control Device (CCD), used for dealing with interactive elements and located at the pedestal.
The MC-21 cockpit information field is managed by the following controls panels, which is shown in figure 4 [7]:

- Display Control Panel (DCP), used for PFD and ND controlling, which is located at the instrument panel;
- Trackball Control Panel (TCP), used for dealing with interactive elements, pages reconfiguration, and located at the pedestal.

Considered systems include several control panels for the cockpit information field management. These panels are located in different parts of the cockpit. So, to change a displayed information configuration, the pilot has to perform several actions and move the focus of attention several times. Obviously, in this case, the crew workload significantly increases.
In the automotive industry and on some business aircraft rotary knob control panels, which include different buttons and a knob, are used to control the information field [8]. Solutions from various manufacturers such as Audi, BMW, and Mercedes are shown in figure 5.

Figure 5. Rotary knob control panel.

In this paper, the use of a similar solution for managing the information field of the aircraft cockpit is proposed.

3. Methodology description
Applying rotary knob control panel, consisting of knob having 4 degrees of freedom (left-right, up-down, rotation and pushing) and three buttons (“BACK”, “MENU” and “CLR”), is described below.

In this paper, the methodology application is shown for controlling the cockpit information field consisting of five indicators. However, this solution can be scaled and applied to cockpits with another structure. Each multifunctional indicator is divided into two equal-sized and independent information displaying zones.

To navigate through pages, the configuration menu is used. The menu is constantly displayed at the top of the screen.

In accordance with the proposed methodology, information field control is divided into three levels [9]:

1. Active zone selection where a pilot needs to make changes. At the outer indicator only the HSI zone is available because the PFD zone cannot be changed.
2. Desired page selection.
3. Selected page setting. For example, text messages clearing or turning on of displaying different elements on ND.

The main element by which the control is carried out is the focus. It is a frame that circles an element with which a pilot needs to perform some action. The focus is constantly displayed, thereby ensuring the pilot’s awareness of which display element he is currently interacting with. An exception is the EWD page—due to the large amount of displaying information, displaying the configuration menu and the focus is turned off after 5 seconds. In order to turn it on again in the current configuration, the pilot has to perform any action with knob or press “BACK” or “MENU” button.

At different control levels, the focus type changes as follows:

- at the first level, it is a frame around the perimeter of the entire page, as well as a zone with the text “L” or “R”, which defines the left or right pilot control side;
- at the second level the focus circle tabs of configuration menu that correspond to the displayed page;
- at the third level, the focus is displayed along the perimeter of the element with which the pilot needs to perform an action.
The selection of an active zone is carried out by rotating or deflecting the knob and using the focus. Zones available for changing are shown in figure 6. Color separation is carried out for more explicit identification of the control source. All selectable elements are highlighted in blue for the left side and green for the right side. At the DU1 and DU4 indicators the HSI zone is only available for configuration and for the corresponding control side.

As an example, in figure 7 one of the indicators is shown, on the left of which the focus of the left pilot is displayed, and on the right—the right.

When the pilot is trying to select the zone, which is used by another pilot, the focus does not move and is blinking during 3 seconds and the knob starts to vibrate for the incorrect choice feedback.

In order to move to the second control level, the pilot has to confirm the selection of the zone by pushing the knob.

After that the tab of the configuration menu which corresponds to the active page is highlighted. It means that the control focus moves from zone selection to selection of the page. The focus color is not changed, as shown in figure 8. The displayed page changes without confirmation by pressing the knob when moving through the menu. The menu consists of two
levels. To go from the first level to the second, the pilot has to push the knob or deflect it down. To go back, the pilot has to press the “BACK” button or deflect the knob up.

The third level is available for the HSI, ND, EWD, FMS and RADIO pages. To go to this level, the pilot also has to push the knob or deflect it down for a corresponding menu tab. After that the page elements are highlighted as shown in figure 9. Moving through the navigation display menu also is performed by rotating or deflecting the knob. Text message management is available for the EWD. The “CLR” button can be used for message deleting. To exit from this control level to the previous one pilot has to press the “BACK” button. To exit from any control level to the first level of the configuration menu pilot has to press the “MENU” button.

Proposed methodology involves interaction with interactive pages, such as FMS VCP, also using focus in addition to the cursor. Moving between interactive elements is also carried out by rotating and deflecting the knob and their activation by pressing. For changing digital values, for example, the radio aid frequency or the cruise level can also be changed by rotating the knob in addition to the numeric keypad. An example of moving through the elements of the FMS VCP interactive page and the outside atmosphere temperature (OAT) value changing using the knob is shown in figure 10.

![Image 1](image1.png)

**Figure 8.** Displayed page selection.

![Image 2](image2.png)

**Figure 9.** Navigation display menu and text message area management.

![Image 3](image3.png)

**Figure 10.** Interactive elements of FMS VCP page management.
To validate the developed control logic the simulator of an aircraft indication system was developed and integrated into a logic integration bench. The simulator consists of: 5 indicator models with the described control logic, 2 trackball control panel models, 2 physical Rotary Knob control panels, and 2 display control panels. Several testing sessions were performed with pilots. It was confirmed that the proposed methodology allows us to significantly reduce the crew workload compared to other existing methodologies of modern aircraft cockpits information field controlling.

4. Conclusions

The analysis showed that existing ways of information field control, used on modern aircraft, can lead to the crew workload increasing. To solve this problem, the aircraft cockpit information field control methodology using the rotary knob control panel was proposed. To confirm the proposed methodology efficiency, an aircraft display system simulator was developed. The assessment with the flight crew participation showed that the proposed methodology provides a unified managing philosophy of the whole cockpit information field, including interactive and passive pages. It leads to the crew workload reducing compared to existing solutions.

References

[1] Rouwhorst W, Verhoeven R, Suikerbuijk M, Bos T, Maij A, Vermaat M and Arents R 2017 Use of touch screen display applications for aircraft flight control 2017 IEEE/AIAA 36th Digital Avionics Systems Conf. (DASC) (St. Petersburg, FL, USA) pp 1–10
[2] Socha V, Socha L, Szabo S and Némec V 2014 Air accidents, their investigation and prevention eXclusive e-JOURNAL ISSN 1339-4509
[3] Lim Y, Gardi A, Sabatini R, Ramasamy S, Kistan T, Ezer N, Vince J and Bolia R 2018 Avionics Human-Machine Interfaces and Interactions for Manned and Unmanned Aircraft Progress in Aerospace Sciences 12 1–46
[4] Airbus Group SE 2019 Airbus A350 Flight Crew Operating Manual pp 987–1201
[5] Airbus Group SE 2018 Airbus A220 Flight Crew Operating Manual pp 1177–1421
[6] The Boeing Company 2010 Boeing 787 Flight Crew Operating Manual pp 827–1135
[7] LLC “UAC—Integration Center” 2017 Standard operating procedures with avionics control panels and actuators pp 10–156
[8] Gugenheimer J, Schaub F, Neiswander G, Gumeratne E and Weber M 2018 User Authentication for Rotary Knob Controlled In-car Applications Proc. of the 6th Int. Conf. on Automotive User Interfaces and Interactive Vehicular Applications (Seattle, WA, USA) pp 1–8
[9] Ivanov A S and Neretin E S 2020 Development of methodology for managing the information field inside the cockpit onboard a civil airplane Crede experto: transport, society, education, language 4 55–69