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UNIVERSITY OF ŽILINA

DEVELOPMENT OF FLIGHT INSTRUMENTS FOR GENERAL AVIATION AIRCRAFT

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Abstract

Given the constantly evolving offer proposed for aircraft equipment, the aim of my work is to describe the innovations, that have been implemented in aircraft instruments. The content of the work is divided from the very beginnings of aircraft instruments and their gradual use and expansion. Subsequently, I deal with the data that are displayed by the devices, but also their design and the comparison of the current state compared to the initial versions. Innovations of aircraft instruments are focused on both components and the display of flight data, which leads to simplification of their operation and individual assembly. One of the advantages of modern instruments is their ability to detect errors that may occur during the flight, which serves the pilots to ensure the flight. Furthermore, I focused on the system of collection, processing and evaluation of information, as well as their final production on board the aircraft. My work is mainly focused on the Dynon system, whose functions, display and implementation I described in detail, use and design in aircraft cockpits. The main goal of the thesis is additional processing of information for the subject Aircraft Instruments I and their processing from the student's point of view.

Keywords

Flight Instruments, Flight data, Displays, Inovation, System EFIS, Processing method, System setup, System errors

1. INTRODUCTION

With the growing demand for air travel, they have grown to design, display data, as well as versions that are displayed as accurately as possible and easy for the pilot to read during the flight. A characteristic feature of technical development is, in particular, the simplification of the implementation of aircraft instruments as well as their smaller construction dimensions.

The work describes the gradual improvement of aircraft instruments, their components and the use of new systems in the field of computer technology on board aircraft. The transition from classic, analog instruments to the use of LCD screens has made the components and display of flight data easier to read for the pilot, but they also represent advantages for their installation by relieving the maintenance requirements of aircraft instruments for designers. The components used in the beginnings of aircraft instruments have been replaced by those aircraft, and the structural elements have greatly reduced the weight of the aircraft, which is very sensitive to efficient mediation in air transport. More modern design elements bring many advantages, which are described in the work.

The work is focused on systems installed in the aircraft of the University of Žilina, which are included in the basic training of pilots. The aim of this work is a detailed description of the Dynon system. It contains a description of the SkyView SE system, as well as its settings and extensive data display. The main task is to provide information about the system, its settings and analysis of individual information that the system combines and then processes.

Advanced flight data processing systems include the introduction of Inertial Navigation Systems, an aerometric computer and the introduction of integrated modular avionics, which combines products from different manufacturers into one system. Ensuring fast data processing is beginning to use bus systems, displaying data on screens, which have gradually replaced the classic analog display.

2. MODERNIZATION OF INSTRUMENTATION

Modern technologies have made it possible to introduce electrical flight instrument display systems into the aviation. The information displayed on the screens works with the information from the sensors, while it is transmitted via buses to the on-board computers. which evaluate them. The basic task of the EFIS system is an efficient and reliable replacement of electromechanical instruments as well as gyroscopic instruments. Its great advantage is the relatively simple structural maintenance, as well as the elimination of the high degree of wear of the mechanical parts of analog devices. As regards the operation of instruments combined in the EFIS display, the crew must be sufficiently familiar with and trained in its operation.

2.1. Bus systems

Bus systems are used for data transmission, so-called serial transmission, which we divide into a one-way bus system or a two-way bus system.

The two-way serial system represents the principle of sending and receiving a message by each radio exchange unit - RVJ, based on the use of time multiplexing of messages, which means that at a given moment one RVJ is active and the rest listen.

Half-duplex transmission is a mode of two-way communication - alternately, but at the moment this transmission is only one-way. In half-duplex transmission, one bus circuit of transmitting and receiving RVJ is created. The control of such transmission can be centrally and distributed. Bus control is challenging.

The one-way serial system is a simpler design, as each RVJ uses one bus, a large amount of cabling is created - it reads and monitors all messages [1].

3. MODERN AERONAUTICAL DATA PROCESSING SYSTEMS

EFIS combines information on position, flight speeds as well as vertical speed, flight altitude, slope and more. It also allows you to view the terrain map, plot the terrain, or traffic in space. Further display of meteorological conditions, engine flight data, if the ECAM system is included in the design, while the information is displayed on one or two displays. These are PFD - primary flight display and MFD - multifunctional flight display.

The PFD display includes the basic instruments needed for the flight. In general, it displays altitude, flight speed, vertical speed, position, course, and slope [1,4,5]. The MFD display shows the real situation in the cockpit, it can also display a moving map, approach maps, terrain warnings. The transition from analog devices to LCD displays had several advantages, the most important of which are:

• weight and size reduction,

• prevention of wear of moving parts,

• more efficient and clear data display,

• increased safety due to better readability.

3.1. Displays used in aircraft

Innovations in data display technologies on board aircraft are gradually moving to the use of LCD displays. Although most manufacturers mainly use LCD displays for their equipment, we also encounter the use of CRT displays.

A CRT screen is basically an image rendering of millions of dots in the basic RGB color scale (red, green, blue), which, when in contact with an electron beam in the screen, lights up and renders the desired image [1,3].

At the back of the monitor is a light source, which is most often in the form of a CCR (cold cathode) cathode and is replaced by LEDs. Light passes through the layers and its task is a homogeneous distribution of the light layer on the display surface. The rays pass through a polarizing filter made of liquid crystals. The light is white, after passing through the RGB filter it passes to the polarizing filter. At the top of the display, three layers are introduced, the purpose of which is even light distribution and image quality [1,3]. The use of LCD displays in the cockpits of aircraft brings several benefits. Displays last longer and render images more reliably in a variety of low-cost flight conditions [10].

4. SYSTEMS INSTALLED IN THE AIRCRAFT OF THE UNIVERSITY OF ŽILINA

GARMIN and Dynon systems are installed in the aircraft of the University of Žilina for basic training. As the topic of GARMIN instrumentation has already been processed, the work is mainly devoted to the Dynon SkyView SE system. User manuals for the systems are issued by the companies in English as well as the menu of the instrument system on board the aircraft is displayed in English. For this reason, some terms in the following chapter are given in English, for a better understanding of the system and inefficient use of translations when operating the devices.

4.1. Zlin Z242 L

The Zlín Z 242 L aircraft model has the Garmin G500 TXi system installed, which is displayed on the PFD and MFD. Based on static and total pressure, the pitot-static system displays basic flight data on the primary display unit. This data is processed using ADC - air data computer. Position and direction tracking is provided by AHRS, which is combined into one ADAHRS unit. The basic task of the primary display is: to display altitude, true airspeed, vertical speed, reference position of the aircraft with respect to the horizon, direction and information for navigation in space. The display on the multifunction display is mainly on map information, information about the terrain around the aircraft and navigation information [13].

5. DYNON SYSTEM

Dynon produces devices in aircraft cockpits with lower display complexity and cost. The company's main goal was to effectively reduce the cost of their systems, making them significant. This is mainly a limitation of functions for IFR flights. The devices are intended for use in VFR flight conditions. SkyView SE displays operate in PFD mode - primary flight display or EMS - engine management system.

5.1. Viper SD-4 RTC - DYNON EFIS-D600/900

The Viper SD-4 RTC model is equipped with the Dynon EFIS D900 system using the SkyView SE display. These systems are suitable for VFR flights. Flight data can be configured on board the aircraft using the SkyView system according to your requirements.Dynon EFIS-D900 is an electronic, information system with a 10-inch display that combines several aircraft instruments such as a magnetic compass, variometer, transverse inclinometer, flight clock and more. It is designed especially for small aircraft of general aviation. The information is displayed differently, depending on the screen layout selected.

The displays are powered in series via five ports connected to the SkyView Display Harness (SV-HARNESS-D37). These displays use LED backlighting (described above), precisely because of their advantages, especially regarding uniform backlighting and also reduced energy consumption [7,9].

Table 1: Dynon displays configuration [7].

Parameters	100%	80%	50%	20%	OFF
PFD	✓	✓	✓		✓
EMS	✓		✓	✓	✓

5.2. USB ports

SkyView has three inputs to USB ports, two in the back and one in the cable harness, which is used for more accessible USB connection to the system. Two of these inputs are for firmware for system updates, backup and the ability to download data from the database. Only one USB key can be connected at a time [7].

5.3. System operations

Operation is via eight buttons located on the bottom edge of the display frame and two joysticks. They are used for various instructions, including the possibility of switching the system on and off, navigating the systems and also for adjusting values [7]. The display can be in display mode 1/1, which means display in full screen, or in mode 1/2 or 1/5. This is the data of the PFD display and information about the engine, when we select how much space the data should take up. Table 1 Percentage display of individual parameters on the Dynon display [7].

5.4. Display synchronization

If there are multiple displays on board the aircraft, SkyView SE will synchronize the information between these displays. When there are multiple displays on the aircraft, it is only necessary to make changes, set data and acknowledge alerts (if they appear) on one display. Certain data that can be set up with SkyView SE is intentionally not synchronized. For example, the layout of the data displayed on the screen is different for each display and is not synchronized. If Ethernet access is on board, it is possible to link airport frequency data from the radio database. If there is no Ethernet connection, airport frequency data cannot be synchronized between screens [7].

5.5. Skyview compatible applications programs

SkyView systems allow you to synchronize application programs from a tablet or mobile phone using a Wi-Fi adapter. These programs include the possibility of flight planning and preparation. Subsequently, by connecting to the SkyView system, this plan can be displayed on the flight display. These are applications from Seattle Avionics, FlyQ, ForeFlight Mobile, PocketFMS Easy VFR, iFlyGPS and SkyDemon [11].

5.6. Main features of SkyView SE

Leading features of this system include the ability to monitor engine parameters, display devices on the screen and in the format of analog devices, autopilot installation, angle of attack monitoring and compatibility with ADS-B Out [6,8].

<u>The main parts displayed by the PFD</u>

The primary flight display combines information:

• Air speed as well as its errors, trend indicator.

• Position indication together with warning of excessive approach angles.

• Altitude information, barometer settings and altitude.

• Vertical speed along with its error.

• Directional gyroscopes.

• Transverse inclinometer.

• Indication of the angle of attack.

• Wind information.

The information combined on the PFD display is generated from calibrated sensors that are part of the SV-AHARS-200/201 module. The devices have fixed parts. Measurements in all three directions are using accelerometers and thus sensors: rotational speeds (rotation around three axes), pressure transducer (air data) and magnetometers (measuring the magnetic course on all three axes). The sensors are the core for Dynon Air Data Attitude and ADAHARS [7].

5.7. ADAHARS

The Air Data and Attitude Heading Reference System is a system that groups position, course, and air information. It is a reference system using MEMS sensor sensing technology to measure magnetic, inertial and air data.

5.7.1. <u>How does ADAHRS works</u>

Alttitude calculation - the display of the artificial horizon SkyView SE is generated by an algorithm using sensor data. The system uses air speed to make the calculation as accurate as possible. If the pitot sensor input is blocked, GPS information will be used. If there is information in the GPS system, it notifies it with a GPS ASSIST message.

Magnetic compass - the accuracy of synthetic vision, map performance and autopilot are affected. Therefore, it is necessary that the Mk - magnetic course be as accurate as possible. The ADAHRS and magnetometer must also be installed and calibrated correctly to work in any position. As the system is sensitive to such magnetic interference, the SV-ADAHRS-200/201 and the installation of a remote gravity magnetometer outside the box are implemented so that its interference is minimal. SV-MAG-236 serves these requirements.

Engine data - this information is obtained from SV-EMS-220.

Engine Monitoring sensors - t measures various parameters such as rpm, line pressure, EGT exhaust gases, CHT cylinder head temperatures, oil, fuel and coolant pressure, fuel level, voltage, current. The system can display the temperatures of all cylinders on a display for easy comparison by the pilot.

GPS receivers - SV-GPS-250 and SV-GPS-2020 modules are used for this. These are 5Hz GPS receivers that receive WAAS-enabled information that is designed specifically for this system. The data is in NMEA format. The SV-GPS-2020 module is compatible with ADS-B Out 2020.

Uninterruptible power supply - SV-BAT-320 battery serves as an alternative power supply for operation at least 60 minutes from the moment of electrical system failure.

VHF radio - module SV-COM-25 integrated VHF radio has two modules SV-COM-425 and SV-COM-PANEL with a spacing of 25kHz.

Optional control panel - SV-KNOB-PANEL is an optional module that consists of three buttons and is recommended especially in systems with autopilot installed. Used to correct the most common errors in the system.

Autopilot function - using SV32, SV42 and SV52 and allow this system to operate in autopilot mode [7,8].

6. DATA COLLECTION METHOD

The entrance to the system is located on the left wing from the bottom, from where the total pressure is led to the ADAHRS and the barometric air velocity indicator. The approach angle is processed in the ADAHRS. In the upper part of the vertical stabilizer we find a static pressure sensor for measuring its value, from where it is transmitted to the ADAHRS system, which then evaluates the data for the analog speedometer and analog altimeter [7,12, 16].

Course information and barometric data are transmitted from the ADAHRS system to the EFIS system and EMS, which are collected in the Data Bus in digital form [7,12,18].

Engine information shows the engine intake manifold pressure as well as the speed on the EFIS page. To obtain the measured parameters, it is necessary to correctly install the pressure sensor and the tachometer drive, using an EMS-based configuration that is connected to the DSAB [7,17,19].

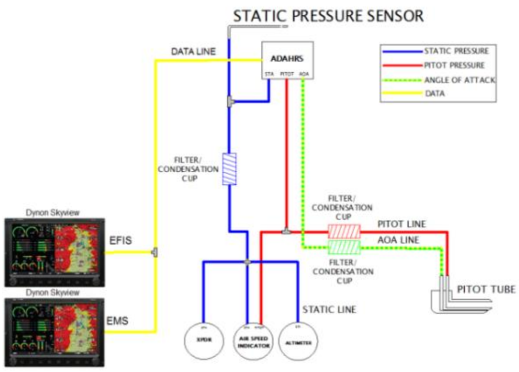

Figure 1: Dynon EFIS and EMS system. [7]

6.1. Message alerts, notifications and alerts

Button 8 is used for the notification area, where all system messages are accessible. This area is used to inform about messages and alerts. In SkyView, these alerts are categorized into 3 areas according to the severity and impact of the flight. These areas are divided into messages, alerts and warnings.

6.2. System check

SkyView SE obtains data from the ADAHRS system. This data is constantly cross-checked. In the event of a system failure, it switches to backup modules in the event that ADAHRS fails completely. A notification about parameters that are not identical in the system is displayed on the screen. The parameters are cross-checked and include: position, magnetic course, G meter, rotation coordinator, air speed and altitude.

6.2.1. Message alerts, notifications and alerts

Button 8 is used for the notification area, where all system messages are accessible. This area is used to inform about messages and alerts. In SkyView, these alerts are categorized into 3 areas according to the severity and impact of the flight. These areas are divided into messages, alerts and warnings.

Breakdown of messages by severity:

1. MESSAGE - Advisory report.

2. CAUTION - Abnormal condition, but not critical. There may be an increase in the pilot's workload.

3. WARNING - Critical condition. The need for an immediate solution affects flight safety.

In a situation where the system detects a message or a critical or abnormal condition, a visual indication is displayed in the notification area. This label appears and flashes until the user opens the notification area. If there are multiple alerts in the system at the same time, the system points to the alert with the highest severity.

CAUTION Warning - When the system detects a second severity error, a CAUTION message, it will display a flashing message in the display bar. The following events occur with this alert:

- If there is an audible warning for a given error, it will be played as soon as the error is detected by the system.

WARNING - A WARNING warning is displayed when the system evaluates a system fault with the highest severity. Whenever this error is evaluated, a red warning is triggered. The following events may occur:

- If an external alarm check is installed, it will flash. This represents errors that are due to EMS - Engine Malfunction / Engine Activity Report.

- If there is an audible warning for a given error, it will be played as soon as the error is detected by the system.

- If the origin of this error is an engine parameter on the ENGINE page, this parameter will be highlighted in red and will flash at the same time.

Motor status warnings are only displayed if the sensors are correctly activated and configured. If the sensor alarm is configured as off, the error will not appear on the display even if the sensor measurement is recorded as a third level alarm.

7. CONCLUSION

Instrument development is an essential part of general aviation. Aviation personnel need to be sufficiently qualified and familiar with the systems installed in the aircraft they operate. We have seen the greatest technological progress in aircraft instruments since the Second World War. Many changes have been implemented since then. Given the rapidly evolving technology in the field of aviation, we can consider this development to be a great step forward and a benefit for aviation personnel in terms of simplifying the acquisition of flight information.

The aim of the bachelor thesis was to approach the innovation in the display and design of aircraft instruments, which have been carried out since the beginning of instrumentation. In the bachelor's thesis, we also focused on the benefits for aviation personnel in terms of the effectiveness of the use of new technologies on board aircraft, as well as their effective impact on the design characteristics of aircraft. The main benefit of these innovations is the ability to display warning messages and self-detection of certain problems that we may encounter during the flight as well as during operation. When using displays on board aircraft, we relieve aircraft components from heavy mechanical parts of initially used analog instruments, but it also represents a great benefit for pilots in terms of the ability to configure the display of parameters as well as the implementation of flight data according to their preferences.

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