Peculiarities of exploiting integrated systems of fifth generation aircraft

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Abstract. Researches of information of integrated displays in civil and military aviation of Ukrainian and foreign manufacturers were made. Experiment which included flight in normal conditions and critical instrumental failure was performed. Conclusions were made. And the concept of new integrated systems was created.

1. Introduction

Studies have shown us that the complex of standard digital flight and navigation equipment is almost completely digital. Unlike analog flight and navigation equipment, here sensors, calculators, indicators are made on a digital element base, all communications between the systems of the complex are also digital.

The main directions of the development of avionics is the increasing use of microprocessor devices and digital computers in it, which in their computational and logical capabilities of the digital element base surpass the analog, and promising intellectualization capabilities of flight and navigation systems.

The following factors contributed to the transition to digital flight navigation equipment:

- high manufacturability, small overall dimensions, weight and cost of the digital element base;

- the ability to solve a large number of logical problems and a simpler, more reliable, and deeper organization of the built-in control, which allows covering almost all the equipment of the complex;

- obtaining high reliability through the use of structural and information redundancy methods and a great opportunity for standardization and unification of equipment;

- reducing the workload on the crew through the use of digital systems for electronic display of information on color displays.

From foreign data it follows that the transition to digital systems in the aerobatic part of the complex allows:

- reduce its cost by 20 ... 40%;
- 75% reduce the complexity of maintenance;
- 30 ... 50% - the number of cases of non-fulfillment of the flight program due to a flight and navigation systems malfunction;
- 50% reduce losses due to damage to the PNA.

The motoric load on the crew is significantly reduced. So, depending on the stage of the flight, the load on the commander of the ship decreases by 10 ... 35%, on the second pilot - by 25 ... 45%, on the flight engineer - by 30 ... 60%.

The use of ARFCS primarily provides a significant reduction in the weight of the control system, which on critical aircraft is of critical importance. It also provides more flexible layout options, often allowing you to position the control system in almost any accessible place on the plane. By the way, that's why fly-by-wire control is still the most popular because it is not as complicated and moody as fly-by-light (using optics) or fly-by-wireless (with using wireless technology). Reducing weight and simplifying the layout allows you to enter additional circuits that provide normal control of the aircraft in a state of failure of one of the previously worked circuits. It allows, if possible, to reduce the human factor by controlling the flight parameters in automatic mode and adjusting the pilots' commands. It monitors the status of critical aircraft systems in real time, which allows you to detect, track and, if possible, correct the error in the shortest possible time [1].

2. Adaptive interface

The adaptive interface filters the information and determines the order of presentation of the remaining (sets priorities). If the pilot is actively engaged in any activity, the adaptive interface itself can solve the problem and perform a corrective action by informing the pilot. Along with the external situation, the adaptive interface also evaluates the pilot’s condition, its load and ability to cope with the prevailing adverse circumstances. As a result of this assessment, the interface adjusts to the state of the pilot.

Compared to the conventional pilot-aircraft interface, adaptive performs three additional functions - assessing the situation, assessing the status of the pilot, and configuring the interface. Assessment of the situation is made according to the information on-board systems. The components of this situation are the external conditions and the state of the aircraft. External conditions include, first of all, the proximity of the earth, weather, position and intentions of other aircraft that are nearby. The state of an aircraft includes its position in space, the predicted trajectory and serviceability.

As a result of assessing the situation, the degree of tension, threatening dangers and, as a consequence, the level of pilot load are determined. Pilot actions are also predicted. This is necessary in order to, on the one hand, be ready to support these actions and change the interface in accordance with them, and on the other hand, to find out if the pilot is taking measures to avoid danger. If he does not do anything, this may be a sign that he is not able to do what is needed (in shock, unconscious) and the automation should intervene in the management.

Another objective of the adaptive interface is to assess the status of the pilot. Under the condition of the pilot is understood his mental state (loading, fatigue) and the degree of participation in management. In this case, an assessment of the pilot load level, made in assessing the situation, and physiological parameters are used.

The status of the pilot and the complexity of the situation are the initial premises for the configuration (adaptation) of the pilot-aircraft interface. This setting affects the content and presentation of information, as well as the degree of participation of automated systems in flight control, power plant and aircraft systems. As a result of the assessments, one of several possible levels of adaptation is selected.

Another task that the adaptive interface is able to solve is adaptation to a specific pilot based, for example, on the level of his training or skill. For an experienced pilot, information may be presented in abbreviated form.

The idea of an adaptive interface is especially popular for military aircraft. The need for warfare significantly increases the pilot's workload and at the same time requires maximum concentration, and large overloads or injuries can lead to a partial or complete loss of the ability to control aircraft and even to loss of consciousness. In these cases, the help of the adaptive interface is quite substantial.

Partially, the ideas of an adaptive interface embody the recently emerged active security systems. Such a system monitors the pilot’s condition according to its physiological parameters and if they show that the pilot is not able to control the plane (for example, is unconscious), the active safety system puts the plane in horizontal flight and leads away towards the base.

It was assumed that the use of electronic display systems should give the pilot a full awareness of the situation, but there is evidence that modern systems, on the contrary, reduce the degree of awareness of the pilot by the situation. Thus, the British Airways (BA) airline, using materials from its own incident database, compared aircraft with the so-called “glass cockpit” (that is, equipped with electronic display systems and automatic piloting systems), and aircraft with a classic cockpit, which has conventional electromechanical appliances. All components of awareness of the situation were higher for the classic cabin. No supposedly inherent “glass cabin” advantages were found. BA analyzed the warning of the proximity of the earth in nightly or difficult weather conditions. The relative share of incidents for the “glass cabin” was 3.5 times higher than for the classic one. There are improvements with respect to navigational errors, but they turned out to be insignificant, and the probability of detecting errors before they became navigational deviations was 2 times higher among the crews of classic cabs, and the probability of detecting already occurred navigational deviations was 2 times higher in “glass cockpits". [3]

The main reason, according to BA, is that the pilot from a participant in the flight turned into an observer. As possible measures, VA proposes:

- manually configure and identify at least one navigation aid during departure and arrival to cross-control the aircraft navigation system and to update the mental model;
- increase the number of manual tasks, such as selecting / changing the autopilot mode, or announce aloud about the changes in the mode (more verbal interaction between the pilots will increase the level of wakefulness and provide cross control of mental models among pilots).

Another goal that was set when introducing electronic display systems was to reduce the number of pilot errors. However, it turned out that the computerization of the cabin gives rise to new types of errors. First of all, we can talk about the loss of vigilance: pilots tend to blindly rely on a computer. American scientists from universities in Chicago and San Francisco conducted research on a flight simulator with 80 volunteers, which were divided into 2 groups. One half flew with traditional instruments, and the other half - in cabins equipped with electronics, as well as traditional instruments for control. Before the flights, the participants were told that traditional devices are absolutely reliable, and computers are reliable, but not faultless. Studies have shown that despite this warning, people tend to rely entirely on computers and do not pay any attention to traditional appliances that clearly show problems. If the computer offered an erroneous action, then in 65% of cases this action was performed, although other indications did not confirm it. If you needed to take some action, but the computer was silent, then in 41% of cases the desired action was never performed (in the group with traditional devices only 3% of the actions were skipped).

Another typical example. Pilots made training flights on a simulator with an electronic indication and alarm system EICAS, similar to that used on a Boeing 747-400 aircraft. Before the flight, they were reminded that there were 5 engine fire indicators in the cockpit. Nevertheless, if EICAS reported an engine fire, almost all pilots immediately turned off the engine, although other indicators did not confirm this information. After the flight, the pilots themselves recalled that it was dangerous to turn off the engine without checking the fire information.

Another study compared pilot behavior with paper operations and electronic checklists. Pilots with electronic listings turned off the engine 3 times more often by mistake.

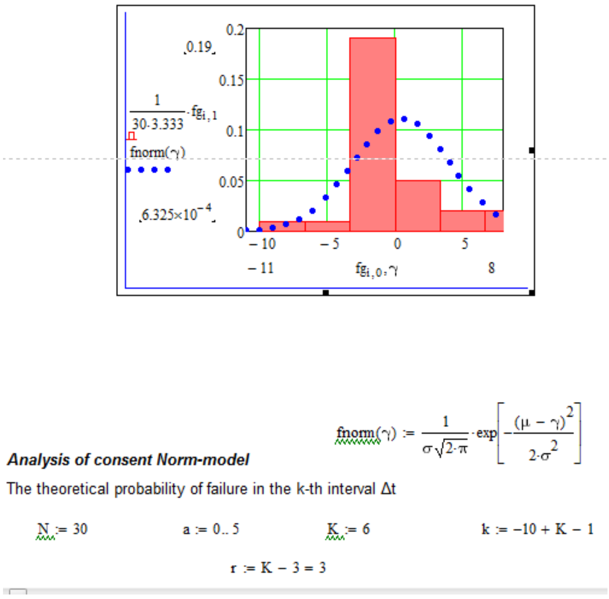
Researchers explain the described behavior by the following human qualities:

- Cognitive laziness. Most people choose the path of least mental effort. With computers that control the situation, pilots do not bother to double-check.
- Social lounging. People basically make less effort if they do work together with someone than when they work on their own. When a computer is a member of the team, the same trend is observed.
- Spraying responsibility. Sharing work with a computer, people tend to shift to a computer, as a member of the team, part of the responsibility.

- Submission to authority. A person is inclined to obey the requirements of an authoritative person. The computer is often perceived as such authority, which is left with the privilege of making decisions [21].

From all that has been said, one can draw the following conclusion: electronic systems are needed not to reduce the pilot's participation in the piloting process, but to simplify this task for him. A good on-board information system is not one that unloads the pilot as much as possible, but one that leaves the pilot in the control loop, fully aware of the situation, while avoiding overloading it.

Calculations for roll



$$fnorm(\gamma) := \frac{1}{\sigma\sqrt{2\cdot\pi}}\cdot \exp\left[-\frac{(\mu-\gamma)^2}{2\cdot\sigma^2}\right]$$

Analysis of consent Norm-model

The theoretical probability of failure in the k-th interval Δt

$N := 30$ $a := 0..5$ $K := 6$ $k := -10 + K - 1$

$r := K - 3 = 3$

Figure 1. Norm-model of distribution.

$$fnorm(\gamma) := \frac{1}{\sigma\sqrt{2\cdot\pi}}\cdot \exp\left[-\frac{(\gamma-\mu)^2}{2\cdot\sigma^2}\right]$$

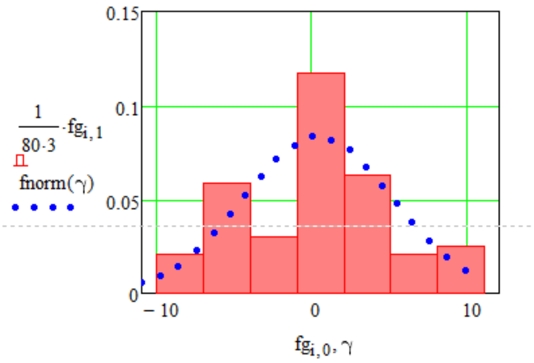


Figure 2. Norm model of distribution.

Calculations for pitch

Normal

$$fnorm(\theta) := \frac{1}{\sigma\sqrt{2\cdot\pi}}\cdot \exp\left[-\frac{(\mu-\theta)^2}{2\cdot\sigma^2}\right]$$

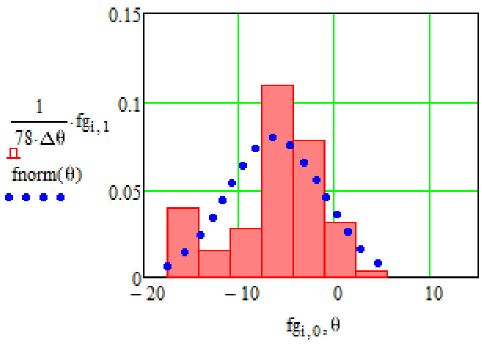


Figure 3. Normal distribution graph.

Lognormal LN

$$m := \mu$$

$$\sigma := \sqrt{\ln\left[\frac{d + (m - q)^2}{(m - q)^2}\right]} = 0.428$$

$$\mu 1 := \ln(m - q) - \frac{\sigma^2}{2} = 2.325$$

$$fln(\theta) := \frac{1}{(\theta - q)\cdot\sigma\cdot\sqrt{2\cdot\pi}}\cdot\exp\left[\frac{-(\ln(\theta - q) - \mu 1)^2}{2\cdot\sigma^2}\right]$$

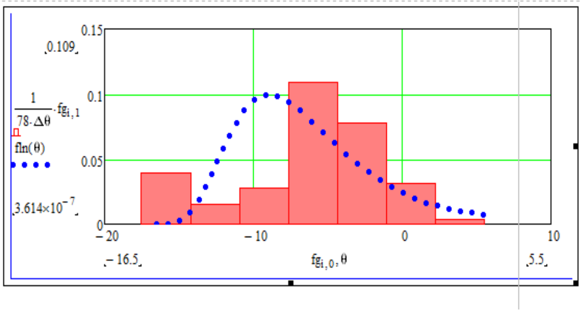


Figure 4. Logonormal distribution graph.

3-parameter Weibull distribution

Scale parameter $a1 = 10.258$

Form parameter $b = 1.8$

Shift parameter $q = -17.5$

$$\theta := -17.5 .. 6$$

$$fv(\theta) := \frac{b}{a1}\cdot\left(\frac{\theta - q}{a1}\right)^{b-1}\cdot e^{-\left(\frac{\theta - q}{a1}\right)^{b}}$$

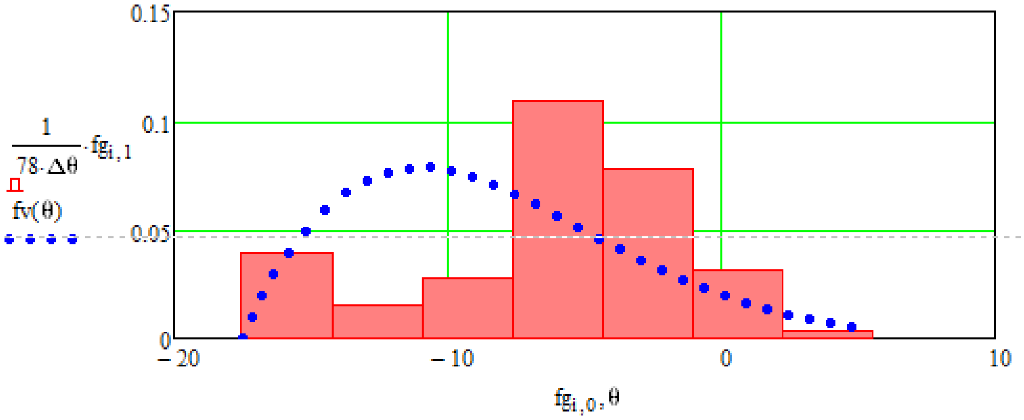


Figure 5. Weibull distribution graph.

Conclusions

Modern aircraft is now a flying computer, which helps pilot in operation and troubleshooting, but it is still not perfect. Too many risks we have and too many confirmations we saw showing us that our aircraft is still far from perfect.

Learning from our past mistakes we may say that experienced pilot can still operate the aircraft with faulty device, but with proper training. To increase the quality of operation and awareness in emergency situations it is necessary to complete trainings aimed to reduce stress level.

References

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