Katarzyna Brzeska
ORCID: 0000-0002-2580-9290
Katarzyna.Brzeska@polsl.pl
Silesian University of Technology

Mateusz Urzędowski
ORCID: 0009-0008-6375-1908
Mateusz.Urzedowski@polsl.pl
Silesian University of Technology

Jarosław Kozuba
ORCID: 0000-0003-3394-4270
Jaroslaw.Kozuba@polsl.pl
Silesian University of Technology

CLASSIC ANALOG PILOT INSTRUMENTS AND "GLASS COCKPIT" IN THE CONTEXT OF PILOT'S PREFERENCES AND CONFIDENCE IN THEIR USE DURING FLIGHT

DOI: 10.55676/asi.v5i1.57

Abstract
With the development of aviation, more and more improvements have been made to existing aviation technologies and applications. These efforts are aimed at optimizing every aviation operation and ensuring maximum safety during flight. Cockpit and in-flight equipment have also begun to seek out new technologies. Since the introduction of new technologies into the aviation world, pilots have been tasked with adapting to new instrument readings. This article present the authors' research to determine the degree of pilots' confidence and comfort in using digital glass cockpit imaging, along with an indication of respondents' subjective opinion of digital and analog imaging of pilot information. The study used a diagnostic survey on a sample of 67 respondents to show the differences in piloting and individual pilots' attitudes toward a particular way of visualizing instrument indications in the cockpit. The analysis of the data showed that the vast majority of pilots have experience in performing aircraft operations in a "glass cockpit" and overwhelmingly prefer such a display of indications or do not experience significant differences in piloting in the context of instrument display. Respondents note differences in flying with digital versus analog equipment. In addition, they indicate that they are much more likely to make mistakes resulting from misreading pilot information when using analog flight instruments. At a time when "glass cockpits" are becoming more widely used in general aviation as well, it is necessary to know the differences resulting from the different way of presenting information, but especially the preferences of the pilot crews, who are directly responsible for flight safety.
***Keywords**: air navigation, analog instruments, glass cockpit*

KLASYCZNE ANALOGOWE PRZYRZĄDY PILOTAŻOWE I „GLASS COCKPIT" W KONTEKŚCIE PREFERENCJI PILOTA I ZAUFANIA DO ICH UŻYWANIA PODCZAS LOTU

Streszczenie
Wraz z rozwojem lotnictwa wprowadzono coraz więcej ulepszeń w istniejących technologiach i aplikacjach lotniczych. Wysiłki te mają na celu optymalizację każdej operacji lotniczej i zapewnienie maksymalnego bezpieczeństwa podczas lotu. Zmiany te dotyczą również technologii kokpitu i wyposażenia pokładowego. Od czasu wprowadzenia nowych technologii do świata lotnictwa piloci mają za zadanie dostosować się do nowego odczytu wskazań przyrządów. W artykule przedstawiono badania autorów, które miały na celu określenie stopnia zaufania i komfortu pilotów w korzystaniu z cyfrowego obrazowania szklanego kokpitu, wraz ze wskazaniem subiektywnej opinii respondentów na temat cyfrowego i analogowego obrazowania informacji pilotażowych. W badaniach wykorzystano sondaż diagnostyczny na próbie 67 badanych w celu pokazania różnic w pilotażu i indywidualnym podejściu pilotów do konkretnego sposobu wizualizacji wskazań przyrządów w kokpicie. Przeprowadzona analiza danych wykazała, że znaczna większość pilotów posiada doświadczenie w wykonywaniu operacji lotniczych na statkach powietrznych w „glass cockpit" i w znacznej większości preferują takie zobrazowanie wskazań lub nie odczuwają znaczących różnic w pilotażu w kontekście zobrazowania wskazań przyrządów. Badani zauważają różnice w lotach z cyfrowym a analogowym wyposażeniem. Ponadto, wskazują że znacznie częściej popełniają błędy wynikające z błędnego odczytu informacji pilotażowej przy wykorzystywaniu analogowych przyrządów pokładowych. W czasach, gdy „glass cockpit'y" są coraz szerzej stosowane również w lotnictwie ogólnym, konieczne jest poznanie różnic

wynikających z odmiennego sposobu prezentacji informacji, ale przede wszystkim preferencji załóg pilotów, którzy są bezpośrednio odpowiedzialni za bezpieczeństwo lotu.
Słowa kluczowe: *nawigacja lotnicza, analogowe przyrządy, glass cockpit*

1. Introduction

The cockpit is the pilot's primary workplace. Aviation, like any other industry, faces economic pressures from the company (airline) versus maintaining safety levels. Providing crews with all the necessary equipment and providing the necessary emergency training in flight simulators becomes essential in the entire consideration of flight operations[1]. Thus, the pilot crew must be familiar with the cockpit and all its equipment at a high level[2, 3, 4]. For years, aviation has focused on adjusting cockpit ergonomics as much as possible. It is necessary to provide him/her with the appropriate ergonomics of the cabin and to lay out the on-board instruments in such a way that they do not pose a problem for the pilot's crew[5]. Thus, cockpits are created in such a way as to minimize the pilot's workload[6]. The pilot from on-board instruments receives the information necessary to perform the task, on the basis of which he/she is to make a decision and appropriate action by a human[7]. The human factor is extremely important in any kind of consideration of flight safety. It should be emphasized here that it is important insofar as, with inadequate management of human resources and the constraints under which man and his psycho-physical capabilities are placed, the level of safety of flight operations performed decreases dramatically. Thus, there is a need for pilot crews to have a high level of situational awareness[8]. Situational awareness and overall awareness of the environment in which the pilot finds himself is a key factor in the process of making an appropriate decision. The quality and comfort of the cockpit adaptation directly affects the quality and safety of the flight. The reading of any instrument readings should be maximally optimized in terms of human adaptations, at a time when the largest percentage of aviation accidents and incidents are caused by human error. The way the information is presented should ensure quick comfortable and easy-to-read reception of the information indicated on a given instrument. Incorrect way of presenting the information causes errors in the decision-making process, by the wrong interpreted (received) information[9]. Today's times necessitate increasing automation and, consequently, a different adaptation of the pilot to receive instrument information. The quality of training and skills acquired during his are undoubtedly important, but also comfort mental plays a significant role in the number of errors during operation. The environment that surrounds the pilot, but also every person in everyday life, directly affects a person's decision-making process and how he or she perceives a given piece of information[10]. This fact depicts how important it is nowadays to study the readiness of pilots to react quickly, presented on the LCD display of the glass cockpit. The confidence and comfort use of such a solution, directly translates into flight safety. Confidence regarding reception of a given piece of information is not only regarding the ability to correctly read the presented information, but also emergency situations, during which quick action is necessary. Today's technologies pose new issues and problems for researchers in the field of humans and their capabilities. In 1979, the branch of NASA's responsible for studying the human in the field of aviation began to study the human factor in the context of adaptation to the digital cockpit. From a 3-year

[1] J. Kozuba, *Czynnik ludzki – rola symulatora lotniczego w szkoleniu lotniczym*, Logistyka 6, 2011.
[2] B.K. Burian, I. Barski., K. Dismukes, *The challenge of Aviation Emergency and Abnormal Situations*, NASA Report, Ames Research Center (Moffat Field, California: NASA 2005).
[3] B.K. Burian, R.K. Dismukes, I. Barshi, *The Emergency and Abnormal Situations Project*, [in:] ed. T. McCarthy, Proceedings of the ISASI 2003 Conference. Washington, D.C., August, 2003.
[4] A. Turgay, D. Dreyery, F. Pankratz, R. Schubotz, *A generic virtual reality flight simulator*, 2016.
[5] F. Bernard, M. Zare, R. Paquin, J.-C. Sagot, *A new approach for human factors integration into design for maintenance: a case study in the aviation industry*, International Journal of Human Factors and Ergonomics, Vol. 10, No. 2, 2023.
[6] J. Dąbrowska, *Czynnik ludzki w lotnictwie*, Instytut Lotnictwa, Warszawa 2011.
[7] E. Klich, J. Szczygieł, *Bezpieczeństwo lotów w transporcie lotniczym*, ITE-PIB, Radom 2010.
[8] A.-M. Teperi, T. Paajanen, I. Asikainen, E. Lantto, *From must to mindset: Outcomes of human factor practices in aviation and railway companies*, Safety Science, Vol. 158, 2023.
[9] P.J. Barber, S. Folkard, *Reaction time under stimulus uncertainty with response certainty*, Journal of Experimental Psychology, No. 93.
[10] G.B. Moskowitz, *Zrozumieć siebie i innych, Psychologia poznania społecznego, Psychologia XXI wieku*, Gdańsk 2009.

study led by Renewick Curry, Ph.D., it was proven from pilot feedback, that advanced technologies in aviation are as useful, safe and optimal as possible for use by pilots[11].

2. Information imaging systems in the context of ergonomics

For the purpose of flight operations, flight-related activities that are the responsibility of the pilot(s) are understood in the context of receiving and processing information[12]. The degree of efficiency in performing flight tasks of aviation is closely linked to situational awareness, which directly translates into the quality, precision and safety of the execution of a given flight. It determines the correct assessment, decision-making decisions and concrete action[13]. Situational awareness considered as a category in non-technical skills during flight, thus refers to the ability to determine the aircraft in space, but also to work comfortably in the cockpit[14]. This is understood as the ease of reading instruments and the ability to operate them correctly[15]. Thus, it is extremely necessary to have a correct "relationship" between the pilot(s) and the aircraft[16]. The flight deck, from an ergonomic point of view, can be understood and divided into 6 areas. Cockpit ergonomics focuses directly on the pilot, as well as on the cabin equipment itself. The individual components on the basis of which the cockpit, are presented in Table 1. As technology develops and pilots face new challenges (e.g., switching from analog reading of piloting and navigation information to fully digital reading digital), all devices are becoming increasingly complex[17].

Table 1. Ergonomics of the aircraft cockpit

AREA		PRIME ATTRIBUTE
Pilot		View
		Body posture
		Body movements
		Muscle Tension
On-board equipment		Display format
		Display rules
		Faults and alarm
Rudder surface		Rudder mechanism
		Rudder operating principle
Cockpit environment		Light environment
		Color coverage
		Thermal environment
		Free flight area
Flight safety		Integrated design

Source: E.L. Wiener, Human Factors of Advanced Technology ("Glass Cockpit") Transport Aircraft, Nasa Contractor Report 177528, Ames Research Center, Moffett Field, Unites States 1989.

[11] E.S. Neretin., E.M. Lunev, N.M. Grigoriev, A.S. Ivanov, *Aircraft cockpit information field control methodology*, Journal of Physics: Cinference Series, 2021.
[12] B. Grenda, H. Turzyńska, *Czynnik ludzki i jego wpływ na bezpieczeństwo lotów*, ASzWoj, Warszawa 2016.
[13] W. Hengyana, Z. Damin, W. Xiaoru, W. Qun, *An experimental analysis of situation awareness for cockpit display interface evaluation based on flight simulation,* Chinese Journal of Aeronautics, Vol. 26, Issue 4, 2013.
[14] J. Kozuba, T. Compa, *Human Factor – likehood of the air Crew training on situational awareness shape*, Logistyka, nr 3, 2012.
[15] R. Flin, C. Agnew, *Human factors in safety management, Human factors and ergonomics for the gulf cooperation council*, CRC Press 2018.
[16] J. Chen, S. Yu, S. Wang, Z. Lin, G. Liu, L. Deng, *Aircraft Cockpit Ergonomic Layout Evaluation Based on Uncertain Linguistic Multiattribute Decision Making*, Advances in Mechanical Engineering, 2014.
[17] E.L. Wiener, *Human Factors of Advanced Technology ("Glass Cockpit") Transport Aircraft*, Nasa Contractor Report 177528, Ames Research Center, Moffett Field, United States 1989.

The ergonomics of the cabin directly translates into the efficiency of the pilot's work, and thus affects the quality and safety of the flight operation performed. The pilot's reaction time is determined by the time it takes to receive information, process it and finally execute his/her own decision. The received information is divided into specific subsets, where the following data used in flight are distinguished: piloting, navigation, on the technical condition of aircraft systems and installations, on combat resources, tactical, and from imaging transducers and orders from the command center[18].

3. Analog on-board instruments and glass cockpit

The environment, in the context of flight execution safety, consists of two spheres: natural (nature) and artificial, man-made. The natural environment includes weather or terrain, while the artificial environment refers to control system equipment, aircraft equipment, infrastructure, etc. It is further divided into physical, i.e. those elements that have been man-made, and non-physical referring to procedures[19]. With regard to depicting the data necessary for a given flight, aircraft instruments (indicators) are divided into analog, digital, mixed and symbolic. Initially, all aircrafts were equipped with analog instruments. Based on the leaning indicators, specific information is conveyed by a particular instrument. Instruments built in this way (they omit the issue of the overall housing and interior of the instrument) have a dial depicting specific values typical of a particular indicator, and a pointer (or pointers) to represent a specific value. In the case of analog instruments, it is not possible to "quickly" (compared to digital depiction of information) reading a specific value, just by looking at the instrument[20]. A kind of "decoding" of the information, as is the case with, among others, altimeters (Fig. 1). The altitude on such an instrument is indicated by two pointers, where each is responsible for indicating a different magnitude of a different order – the larger pointer indicates thousandths values, while the smaller pointer indicates hundredths values of height. Altitude is scaled in feet [ft]. In addition, there is a window (i.e. Kollsman window) in which a specific pressure is set. On the indicator presented, the indicated altitude is 6500 ft according to a pressure of 29.92 inHg[21].

Fig. 1. Altimeter

Source: J. Chen, S. Yu, S. Wang, Z. Lin, G. Liu, L. Deng, Aircraft Cockpit Ergonomic Layout Evaluation Based on Uncertain Linguistic Multiattribute Decision Making, Advances in Mechanical Engineering, 2014.

---

[18] E.S. Neretin, E.M. Lunev, N.M. Grigoriev, A.S. Ivanov, *Aircraft cockpit information field control methodology*, Journal of Physics: Cinference Series, 2021.

[19] A. Ilków, *Czynnik ludzki w systemie bezpieczeństwa ruchu lotniczego*, Warszawa 2011.

[20] G. Huettig, G. Anders, A. Tautz, *Mode Awareness in a modern glass cockpit attention allocation to mode information*, [in:] ed. R. Jensen, Proceedings of the 1999 Ohio State University Aviation Psychology Conference, Dayton, OH: Ohio State University.

[21] J. Chen, S. Yu, S. Wang, Z. Lin, G. Liu, L. Deng, *Aircraft Cockpit Ergonomic Layout Evaluation Based on Uncertain Linguistic Multiattribute Decision Making*, Advances in Mechanical Engineering, 2014.

On the instrument with a digital depiction of the given information (for example, piloting), in a direct way, concrete value, the information is presented to pilots. In the case of digital instruments, often several instruments are integrated on a single indicator – for example, on the Prmary Flight Display PFD (Fig. 2)[22] . On this example, the indicated altitude value is 14300 ft. Technology is becoming so widespread that presenting instrument indications on glass cockpits is no longer reserved for professional (or military) aviation, but is already making its way into the world of General Aviation[23]. More and more willingly and widely used is this on-board instrument technology, already even in single-engine aircraft. Digital indicators are increasingly present in our lives, so it is not no surprise that they are also increasingly present in aircraft. Instead of the standard dial "clock", indicators with an electronic way of displaying information are widely used[24]. Primary Flight Display PFD in addition to its widespread use in communications aviation, electronics is increasingly finding wide application in small aviation (General Aviation)[25]. On a single indicator we can put many different "instrument indications" at the same time, and moreover, depending on the stage of flight we can change the information displayed on the screen as needed. The PFD system is part of the Electronic Flight Instrument System EFIS, which still includes a multi-function display and crew alerting system EICAS. All such onboard equipment uses electronic LCD (liquid crystal displays)[26].

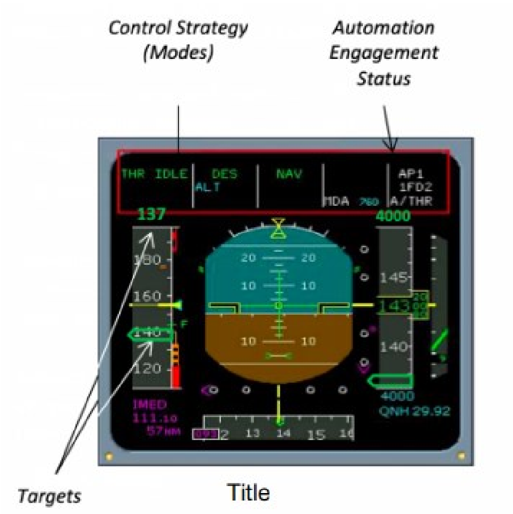

Fig. 2. PFD indicator

Source: Instrument Flying Handbook, Chapters 5-7, Federal Aviation Administration, U.S. Department of Transportation, FAA-H-8083-15B.

Digital displays are becoming increasingly popular not only for transport aircraft, but are also gaining popularity in general aviation (GA). The PFD display (Fig. 2) has an artificial horizon in the main part, which shows a symbol indicating the position of the aircraft. It primarily indicates the aircraft's maneuvers

---

22 L. Sherry, R. Mauro, J. Trippe, *Desgin of a Primary Flight Display (PFD) to Avoid Controlled Flight into Stall*, Engineering, 2016.

23 Z. Polak, A. Rypulak, Awionika, przyrządy i systemy pokładowe, WSOSP, Dęblin 2002.

24 W. Rouwhorst, *Use of touch screen display applications for aircraft flight control*, NLR – Netherlands Aerospace Centre, 2018.

25 L. Sherry, R. Mauro, J. Trippe, *Desgin of a Primary Flight Display (PFD) to Avoid Controlled Flight into Stall*, Engineering, 2016.

26 The Airline Pilots. "EFIS", https://www.theairlinepilots.com/forumarchive/pilotslounge/efis.pdf [accessed: 16.10.2022].

(climb, descent, turns), the slip rate along with the roll angle, the speed indicator, the variometer indicator, altimeter, set pressure, direction and mods that are activated at a given time[27].

Fig. 3. PFD and Garmin G500
Source: G500/G600, Pilot's Guide, Garmin Ltd. U.S.A. 2016.

PFDs presented as in Figure 2 are basic equipment in terms of avionics in civil aircraft. However, it should be noted that they are increasingly used in general aviation GA (General Aviation), thus displacing analog indicators. An example of a PFD in general aviation is the Garmin G500/G600 indicator (Fig. 3). It provides an integrated display system for avionics, combining the presentation of basic pilot data (such as speed or altitude) with navigation information and a moving map[28].

4. Methodology

The investigation at hand was conducted through an online survey encompassing both private and professional pilots, comprising a sample of 67 participants. The survey, executed with strict anonymity and voluntary participation, predominantly targeted aviation students at the Silesian University of Technology. Additionally, a subset of professional pilots was included in the study cohort. Due to the inherent nature of the method employed, statistical errors were not accounted for, and advanced statistical testing was deemed unnecessary.

The research approach centered on analyzing subjective opinions of pilots rather than emphasizing quantitative measurement results, which typically involve the exclusion of values affected by measurement errors according to standard procedures.

The principal hypothesis under scrutiny posited a prevalent inclination among contemporary pilots towards prefering glass cockpits over analog flight instruments in their flight operations. The research methodology employed quantitative techniques to probe preferences in information retrieval from on-board instruments. Furthermore, it sought to gauge the confidence levels and error propensity associated with classical (analog navigation employing traditional aeronautical maps and instruments) versus digital navigation (hinging on the use of glass cockpits).

The initial segment of the survey aimed at gathering demographic data, encompassing age, gender, aviation licenses, and total flight hours accrued. Subsequent sections focused on eliciting participants' experiences

[27] Instrument Flying Handbook, Chapters 5-7, Federal Aviation Administration, U.S. Department of Transportation, FAA-H-8083-15B.
[28] G500/G600, Pilot's Guide, Garmin Ltd. U.S.A. 2016.

with glass cockpits and their preferences concerning the visualization of information within the aircraft's cockpit. These inquiries were designed to ascertain the pilots' inclinations towards the burgeoning trend of digital imaging in aircraft instruments, a trend progressively permeating various sectors of aviation, including general aviation.

5. Results of the study

There is undoubtedly a great need for continuous research and testing of preferences among pilots in the the way they use the devices in question during air navigation. The degree of trust and preference among flying personnel are undoubtedly important in the flight process. They directly affect the safety of each flight operation. For this purpose, a survey was conducted among pilots with varied experience.

During the survey, most of the pilots taking part in the survey were men in the 20–30 years old with a PPL(A) license, as shown in Figure 4–6.

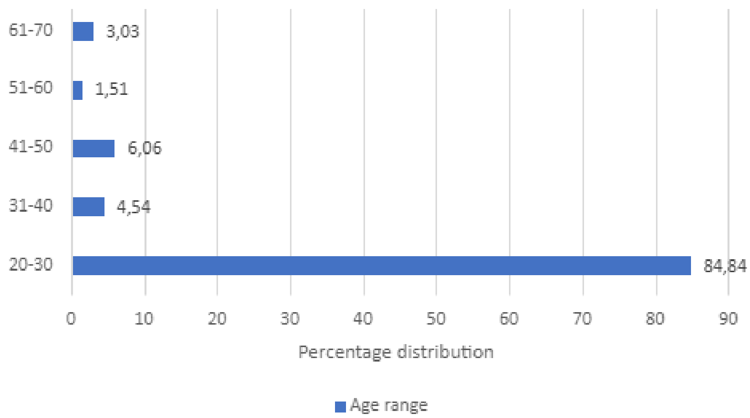

Fig. 4. Age of the surveyed pilots
Source: own study.

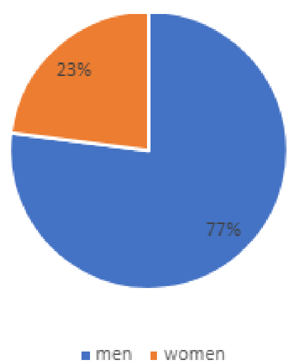

Fig. 5. Gender of the surveyed pilots
Source: own study.

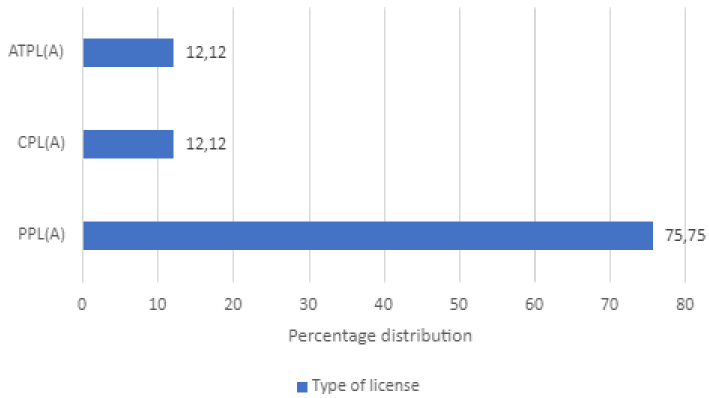

Fig. 6. Type of license held
Source: own study.

Given that the vast majority of pilots surveyed during the study held a PPL(A) license, only the responses of this group of pilots will be presented in the following section.

In the case of flight experience, there was variation among the respondents as to the exact number of hours in Total Flight Hours (Fig. 7):

- 50% of the surveyed pilots put their flight experience at up to 100 TFH,
- on average, it was in the range of 70–80 TFH, where the minimum value was specified at the 30 TFH, and the maximum was 100,
- 50% of respondents wrote that they had between 100 and 400 TFH,
- on average, it was in the range of 200–250, where the minimum value was set at 102 TFH, and the maximum 450.

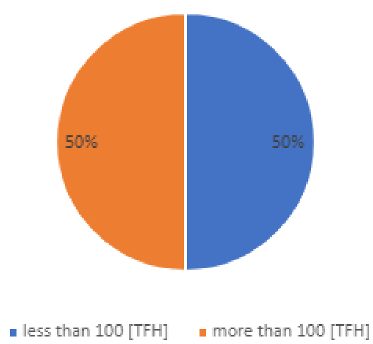

Fig. 7. Flight experience
Source: own study.

The next part of the survey directly addressed the Glass Cockpit experience and the aviation feelings associated with it. 84% of respondents felt they had experience with glass cockpit flights (Fig. 8). Contrasting this with the results in Figure 8, where most of the pilots' flights were on analog instruments, this shows that the contact was more occasional flights to see the quality and comfort of the flight with digital indicators, rather than frequent, regular flights on such instruments. Such a spread of results may also be the effect of a recent change of aircraft, where previously the aircraft were analog. However, one cannot negate the technology encroaching more and more on the aviation world, including at the flight stage in General Aviation GA, where also from the fact of single-engine aircraft equipped with glass cockpits the level of flight familiarity from actual experience is at 16% in the survey conducted. At the same time, the vast majority of respondents have most of their flight experience on aircraft equipped with glass cockpits (Fig. 8) – this was determined by 74% of the surveyed pilots. Similar distribution of results, is the case for individual preferences and experiences of navigation on a based on the glass cockpit versus navigation using analog flight instruments – 82% of surveyed pilots specify that they experience significant differences when flying with digital imagery and the associated quality of piloting.

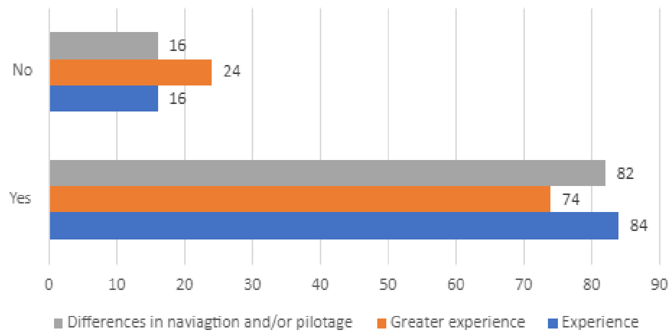

Fig. 8. Flight experience on aircraft with glass cockpit
Source: own study.

Given the different way of reading instrument information and the accommodative abilities of the human eye, it came as no surprise that most marked noticeable differences in the quality of aeronautical navigation and overall piloting skills depending on whether the aircraft is equipped with glass cockpit or analog instruments. These differences manifest themselves on various levels. Among the main factors influencing this distribution of statistics include:

- speed of correct reading of the indications,
- ease of reading,
- friendliness of the interface.

The above questions are closely related to the next question, relating to individual preferences related to performing flight operations on aircraft equipped with glass cockpit (Fig. 9). Here, too, the overwhelming majority of surveyed pilots identified their own preferences for performing flights on aircraft with digital visualization.

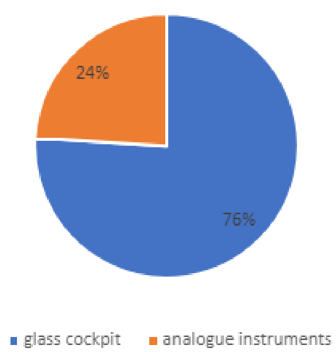

Fig. 9. Preferences relating to imaging on aircraft instruments on-board aircraft
Source: own study.

The last two questions of the survey consisted of marking the appropriate option depending on the given criterion. In the case of preferences for a particular on-board equipment depending on the given criterion (Fig. 10).

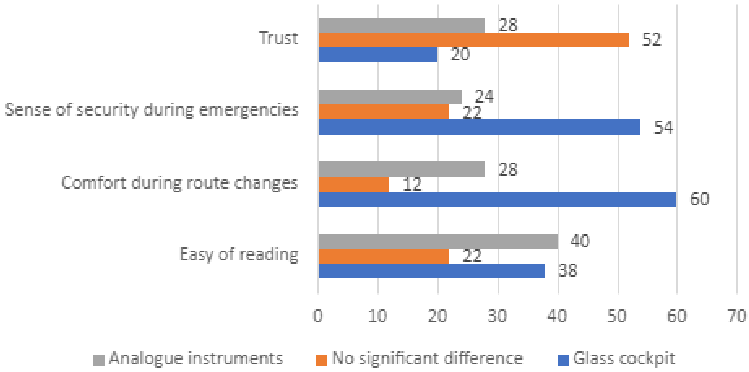

Fig. 10. Preference for glass cockpit, and analog instruments depending on the a particular criterion
Source: own study.

Depending on the individual preferences of the pilots, opinions were more divided over the specific type of display presentation. Within the ease of reading, comparisons of analog instruments with glass cockpit gave very similar results – 40% and 38%, respectively. For 22%, it does not matter more how the indications are presented in the cockpit for the ease of reading the information in question. Also similar results are found in the sense of safety during emergency situations. With this thus, in the event of a messy event, both analog and digital instruments on-board, are comfortable and adequate to respond to an event – 40% and 34%, respectively. The situation is different in the other categories, where the differences are already much more significant. For 54% of of the surveyed pilots with a PPL(A) license, when it is necessary to change tasy in the course of a flight, much more comfort in changing is when flying with a glass cockpit. For only 24% of respondents, greater comfort is in the case of analog indications, and for 22% it does not matter much how the presented pilot information. Thus, this coincides with comfort in navigation (including here flying without changing a predetermined and set route). A significant proportion of pilots (60%) say they feel more comfort in guiding and controlling air navigation when flying on an aircraft with a glass cockpit. For 28% respondents feel more comfortable with traditional analog navigation, while only for 12% of the pilots who took part in the survey, it does not matter much. The final category in this question question was overall confidence in onboard instruments and equipment. At the same time, this is the only category where for more than half of the surveyed pilots (52%) there is no significant difference in the level of their own confidence in the operation and reliability of a given instrument - regardless of whether the indications are presented analog or digital. Nevertheless, it should be noted that 28% of respondents feel greater confidence is felt for analog on-board instruments, and by the same token, only 20% have more confidence has for digital indications.

The last factor examined was the frequency of errors, depending on the type of on-board equipment (Fig. 11).

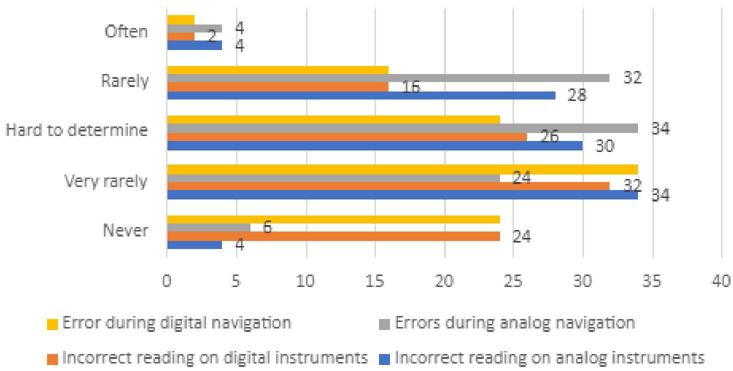

Fig. 11. Incorrect readings depending on the imaging
Source: own study.

The results present a situation in which the undoubtedly lower error rate in the surveyed pilots are characterized by flights on aircraft with digital data imaging. However, it should be noted the fact, that despite the prevalence here of digital instruments, the errors made, both in reading and navigation, are at a similar in frequency. The biggest difference can be seen in the lack of ever making errors, where 24% specified that they had never made errors in flight – both with regard to reading and the actual navigation. Far fewer specified in this category for analog indications – 4% for no errors in reading and 6% for errors in navigation. This shows how much ease, in most cases, makes it easy for pilots to fly with digital flight instruments. The situation is similar for frequent reading and/or navigation errors, where 4% of pilots often have trouble reading correctly on analog instruments and conducting analog navigation, and for 2%, both reading and navigation causes problems, thus causing errors. The frequency of errors made here is a complex process that is influenced by many factors: the accuracy of the instrument's dial analysis, familiarity with the scaling of the instrument, quick ability to judge the purpose of the cues and many others. Parallax error also directly affects the frequency of errors made when using analog instruments. Nevertheless, it should be noted that with analog instruments, the error of reading is much more likely than with digital imaging. Very rarely errors occur in navigation, regardless of the type of imaging of pilot information.

6. Conclusions

Current times necessitate constant change and new applications. New technologies that are increasingly are more widely used in the aerospace industry also make it necessary to constantly monitor the human adaptation to given technological solutions. From the analysis of the survey.

The conducted research and analysis of the obtained results shows that there are still areas where some pilots prefer analog, traditional solutions, but the digital systems for presenting flight parameters and monitoring the its course. Experience and knowledge are still invaluable when considering flight safety, but the there is a growing desire to use digital solutions. This is not just a matter of simple preference, but also of significantly reducing the time to analyze parameters, or the point along the route during emergencies.

According to the team's thesis, equipping aircraft with glass cockpits finds great popularity among pilots. The majority of respondents have glass flight experience (84%), where 74% specify that their experience is greater. This is important because it allows for a real analysis of pilots' preference for a particular type of instrument display. Also, they note differences in navigation and/or piloting (82%). Digital imaging significantly wins for sense of safety in case of emergencies (54%) and comfort when having to change route during flight (60%). Regarding the criterion of trust, for 52% it does not matter what type of instrument imaging is on the aircraft, where for 20% of respondents more trust is in digital imaging. Nevertheless, it should be noted that 76% of the surveyed pilots prefer to perform flight operations on aircraft with a glass cockpit. The findings depict a scenario where pilots surveyed exhibit an undeniably lower error rate when operating aircraft equipped with digital data imaging. Despite the prevalence of digital instruments, it is important to acknowledge that errors in both reading and navigation occur with similar frequency. The most notable distinction lies in the absence of errors, with 24% reporting never making mistakes in flight – whether in reading or actual navigation – when utilizing digital instruments. In contrast, a significantly lower percentage falls into this category for analog indications, with 4% reporting no errors in reading and 6% in navigation. This underscores the apparent ease with which pilots can operate flights using digital instruments in most cases. A parallel trend is observed for frequent reading and/or navigation errors, with 4% of pilots encountering difficulties in accurately reading analog instruments and conducting analog navigation. For 2%, both reading and navigation pose challenges, leading to errors. The frequency of errors is influenced by a complex interplay of factors, including the precision of instrument dial analysis, familiarity with instrument scaling, and the ability to quickly interpret cues, among others. Parallax error has a direct impact on error frequency when using analog instruments. Nevertheless, it is worth noting that reading errors are much more likely with analog instruments compared to digital imaging. Navigation errors are infrequent regardless of the type of pilot information imaging. The team's thesis highlights the widespread preference among pilots for glass cockpits in aircraft.

Furthermore, the findings reveal that pilots operating aircraft with digital data imaging experience a notably lower error rate. Although errors in reading and navigation occur with similar frequency, the key distinction lies in the absence of errors. This emphasizes the apparent ease with which pilots can operate flights using digital instruments. The complexity of error frequency is influenced by factors such as instrument dial analysis precision, familiarity with instrument scaling, and quick interpretation of cues. Parallax error directly impacts error frequency with analog instruments. Notably, reading errors are more likely with analog instruments compared to digital imaging, while navigation errors are infrequent regardless of the type of pilot information imaging.

Bibliography

Barber P.J., Folkard S., *Reaction time under stimulus uncertainty with response certainty*, Journal of Experimental Psychology No. 93.

Bernard F., Zare M., Paquin R., Sagot J.-C., *A new approach for human factors integration into design for maintenance: a case study in the aviation industry*, International Journal of Human Factors and Ergonomics, Vol. 10, No. 2, 2023.

Burian B.K., Barski I., Dismukes K., *The challenge of Aviation Emergency and Abnormal Situations*, NASA Report, Ames Research Center (Moffat Field, California: NASA 2005).

Burian B.K., Dismukes R.K., Barshi I., *The Emergency and Abnormal Situations Project*, [in:] ed. T. McCarthy, *Proceedings of the ISASI 2003 Conference*, Washington, D.C., August, 2003.

Chen J., Yu S., Wang S., Lin Z., Liu G., Deng L., *Aircraft Cockpit Ergonomic Layout Evaluation Based on Uncertain Linguistic Multiattribute Decision Making, Advances in Mechanical Engineering*, 2014.

Dąbrowska J., *Czynnik ludzki w lotnictwie*, Instytut Lotnictwa, Warszawa 2011.

G500/G600, Pilot's Guide, Garmin Ltd. U.S.A. 2016.

Flin R., Agnew C., *Human factors in safety management*, Human factors and ergonomics for the gulf cooperation council, CRC Press 2018.

Grenda B., Turzyńska H., *Czynnik ludzki i jego wpływ na bezpieczeństwo lotów*, ASzWoj, Warszawa 2016.

Hengyang W., Damin Z., Xiaoru W., Qun W., *An experimental analysis of situation awareness for cockpit display interface evaluation based on flight simulation*, Chinese Journal of Aeronatics, Vol. 26, Isse 4, 2013.

Huettig G., Anders G., Tautz A., *Mode Awareness in a modern glass cockpit attention allocation to mode information*. [in:] ed. R. Jensen, Proceedings of the 1999 Ohio State University Aviation Psychology Conference. Dayton, OH: Ohio State University.

Ilków A., *Czynnik ludzki w systemie bezpieczeństwa ruchu lotniczego*, Warszawa 2011.

Instrument Flying Handbook, Chapters 5-7, Federal Aviation Administration, U.S. Department of Transportation, FAA-H-8083-15B.

Klich E., Szczygieł J., *Bezpieczeństwo lotów w transporcie lotniczym*, ITE-PIB, Radom 2010.

Kozuba J., *Czynnik ludzki – rola symulatora lotniczego w szkoleniu lotniczym*, Logistyka 6, 2011.

Kozuba J., Compa T., *Human Factor – likehood of the air Crew training on situational awareness shape*, Logistyka, nr 3, 2012.

Moskowitz G.B., *Zrozumieć siebie i innych, Psychologia poznania społecznego, Psychologia XXI wieku*, Gdańsk 2009.

Neretin E.S., Lunev E.M., Grigoriev N.M., Ivanov A.S., *Aircraft cockpit information field control methodology*, Journal of Physics: Cinference Series, 2021.

Polak Z., Rypulak A., *Awionika, przyrządy i systemy pokładowe*, WSOSP, Dęblin 2002.

Rouwhorst W., *Use of touch screen display applications for aircraft flight control*, NLR – Netherlands Aerospace Centre, 2018.

Sherry L., Mauro R., Trippe J., *Desgin of a Primary Flight Display (PFD) to Avoid Controlled Flight into Stall*, Engineering, 2016.

Teperi A.-M., Paajanen T., Asikainen I., Lantto E., *From must to mindset: Outcomes of human factor practices in aviation and railway companies*, Safety Science, Vol. 158, 2023.

The Airline Pilots. "EFIS", https://www.theairlinepilots.com/forumarchive/pilotslounge/efis.pdf, [accessed: 16.10.2022].

Turgay A., Dreyery D., Pankratz F., Schubotz R., *A generic virtual reality flight simulator*, 2016.

Wiener E.L., *Human Factors of Advanced Technology ("Glass Cockpit")*, Transport Aircraft, Nasa Contractor Report 177528, Ames Research Center, Moffett Field, United States 1989.