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TEST FLIGHTS IN THE AIRCRAFT OPERATION PROCESS

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Abstract

The article presents theoretical and practical aspects of aircraft reliability and safety of the performance of test flights in the operation process. The selected issues of operation of the means of transport in the aspect of the aircraft reliability, as well as the intensity of damage during the performance of test flights were presented. In short, the rules for operating the aircraft during test flights are described. A brief description of the causes of air crashes during test flights was presented, and the main hazards and risk occurring at the same time were shown. Subsequently, the authors' methodology including a diagram for studying the aircraft features in terms of aerodynamic characteristics and performance and a model of the maintenance system of aircraft to perform the test flights, were demonstrated. The elements of the decision-making model, developed for this purpose, were briefly presented, showing the required and defined decision variables, constraints and an objective criterion function. The algorithm of the method was presented, and the examples of practical application and graphical data presentation in the DOSPIL application were indicated. The article was concluded with a short summary in which the main effects and directions of further work were presented.

Keywords: *aircraft test flights, organisation of test flights, testing of aircraft properties*

1. Introduction

Owing to the rapid development of aviation, the tests and studies of aircraft during flight are becoming more and more complex. They are mainly carried out to check newly manufactured or modernised aircraft, as well as to check other aviation equipment.

The development of technology requires qualitative and quantitative assessment of the aircraft performance. The in-flight tests are a speciality, which in addition to the necessary technical equipment, at the same time; require the appropriate methods for their preparation, conduct and control by properly prepared research personnel, especially test pilots.

Figure 1 presents the main tasks of the test pilot during the test flight in order to determine the aircraft properties. It is possible to observe a very wide range based on elements affecting the airframe, engine, various types of systems and, of course, the crew.

With such a wide range of projects necessary to be carried out, it is advisable to develop a tool to support the organisation and security of the performance of test flights, which will make it possible to:

– develop schedules for the implementation of air tasks,
– develop a tool supporting the decision-making process in the selection of a pilot for a given test flight,
– increase the possibility of the risk analysis performance during test flights,

- develop tools for voluntary reporting of irregularities,
- develop tools analysing the operating and maintenance costs.

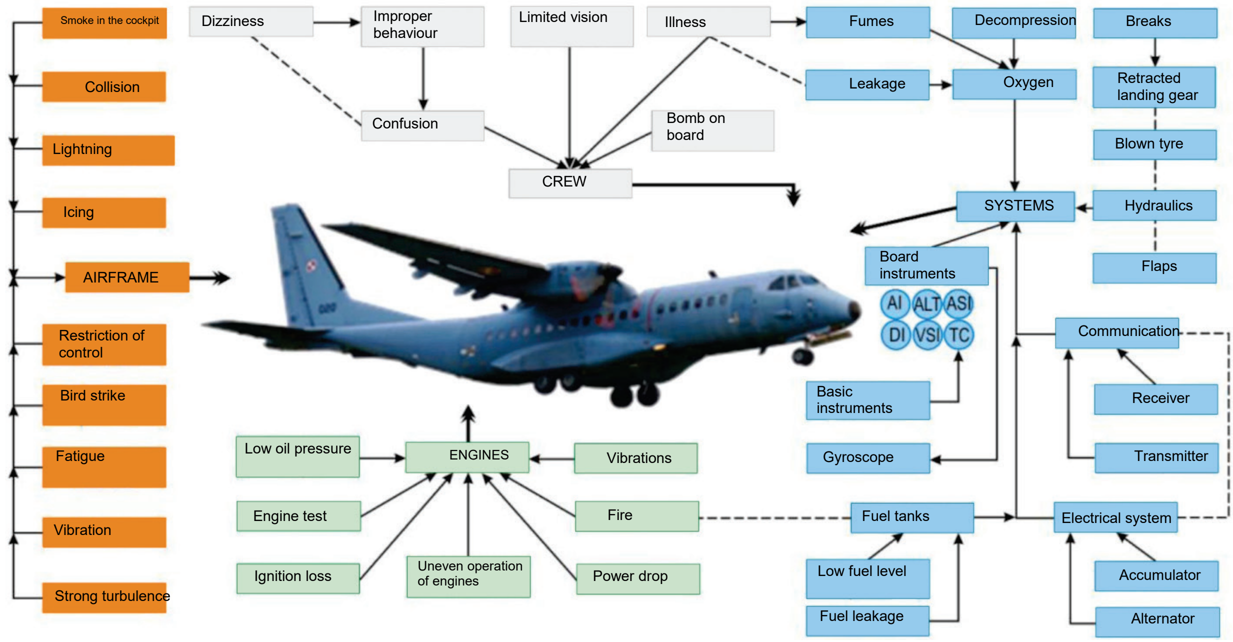

Fig. 1. The main tasks of the test pilot during the test flight in order to determine the aircraft properties

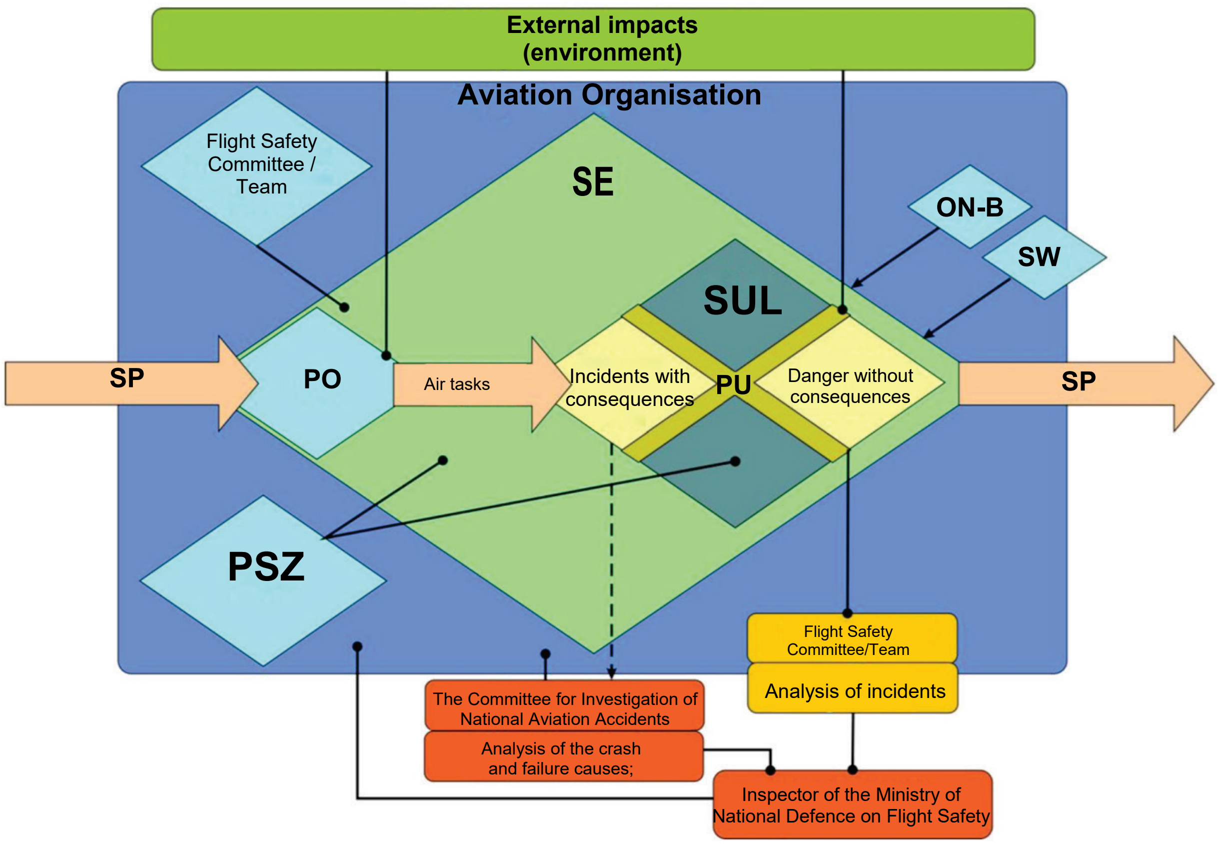

Fig. 2. Diagram of the military aircraft operation system with the flight safety management elements: SE – operation system of aircraft, PU – aircraft operation subsystem, PO - maintenance and repair subsystem of aircraft, PSZ – training subsystem, SZL – logistic security system, SUL – flight insurance system, K – aircraft decommissioning (totalling), SW – aircraft manufacture system SP, ON-B – scientific and research centres

The aerial and technical exploitation system (Fig. 2) represents a set of aircraft, aerial and technical exploitation means, flying personnel, ordinances, and standards specifying the selection and maintenance of the most appropriate scopes of the aircraft technology during test flights and on the ground, as well as the maintenance and restoration of airworthiness of the aircraft technology during flight.

Another important premise was the analysis of the causal groups of aviation incidents during test flights, where a significant impact of the category referred to as the "organisational factor" (O) was found.

This category refers to the flight safety management system in the working environment of the aviation organisational unit.

When assessing the causes of air crashes in the test flights, all aviation accidents that occurred in 1981-2010 were analysed – Fig. 3.

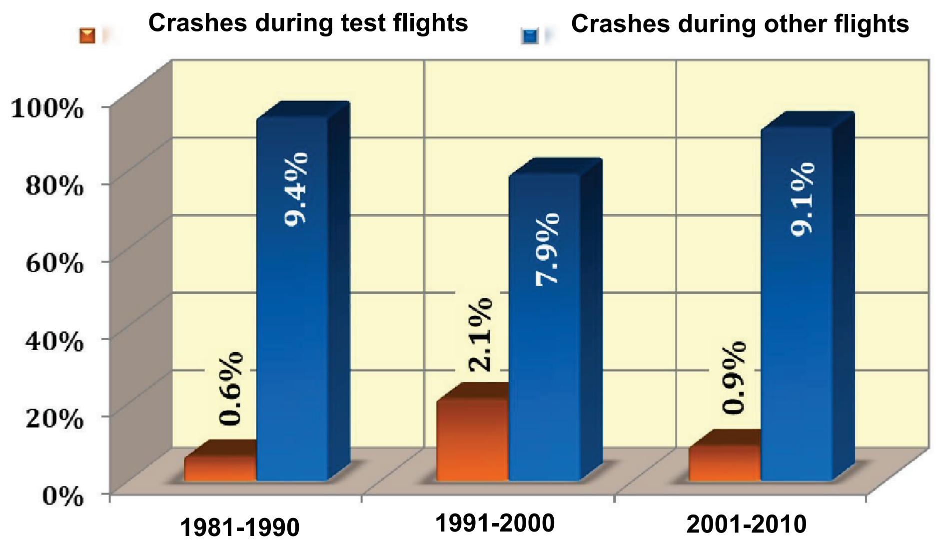

Fig. 3. Air crashes of military aircraft in 1981-2010

In the analysed years, there were 93 aviation accidents of military aircraft. In this group of incidents, the crashes during test flights accounted for 9.7% (specifically, 9 cases), while other air crashes accounted for 90.3% (i.e. 84 incidents).

The most tragic for the test flights were the 90s of the twentieth century, because during that period, every 5th air crash occurred during the test flight (21.0%).

The state of flight safety depends on the entire system of interrelations between the machine and aircraft, a human and an operator using this aircraft, systems securing aviation operations as well as the environment and a degree of difficulty of the performed tasks.

The broadly understood aviation management has a decisive impact on all elements of this system. The system's elements: human – machine – task – environment – management should be considered in systemic terms as a series of mutually interacting factors. Fig. 4 shows such a safety chain that affects the safe flight, in which these elements were distinguished.

Of course, the safety relates to the risk that must be taken during test flights, which is definitely higher than during normal operation of the aircraft.

The risk is defined as a combination of the frequency or probability of the occurrence of unfavourable incidents – dangerous and consequently related to this incident[1]. Among others, for these reasons, the following is necessary:

[1] Singleton's theory (operator-machine), Miller's theory (4xM), Edwards's and Hawkins's theory (SHELL), Reason's theory (cheese), Lomov's and Platonov's theory (common human impact, aircraft, flight management, strategy and technical policy).

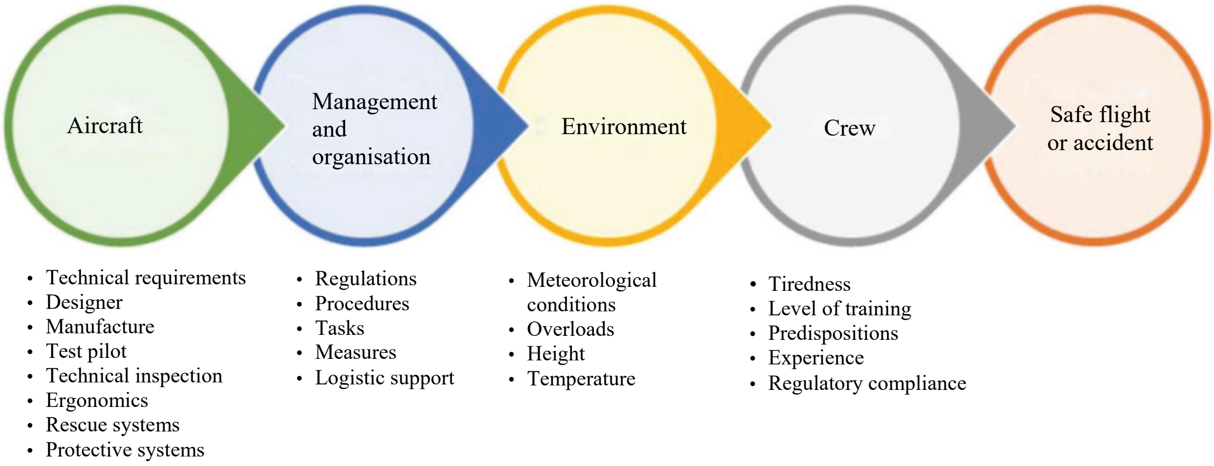

Fig. 4. Safety chain diagram affecting the safe flight performance

– comprehensive approach to the test flight performance processes,
– development of an automated system for supporting the decision-making process while assigning the appropriate personnel to the performing tasks,
– automation of the process of creating schedules for the implementation of air tasks.

2. Process of performing the aircraft test flights

The operational test flights constitute a process, which particular states of the aircraft operation directly depend on, including its reliability, effective use in the aviation training and flight safety.

Such a definition of the issue allows to state that the development of an optimal aircraft selection system for performing the operational test flights and their organisation may constitute the foundation of effective aviation training while maintaining the necessary level of flight safety. In order to solve this problem, a method allowing to comprehensively assessing the reliability of aircraft, aimed at performing the operational test flights, and to assess the safety of performing these flights, was adopted. This method includes both testing of the aircraft characteristics in terms of aerodynamic characteristics and performance, as well as the organization of the maintenance system of aircraft for the test flights.

The determination of efficiency, reliability, and safety indicators is a very difficult and complex problem. Having regard to the above, the performance of test flights is necessary in order to examine the processes occurring during the aircraft operation.

An important aspect is also the formulation of conclusions and the indication of improvement directions of projects in the algorithms of conducting research in the aspect of a human factor having a direct impact on the results of the in-flight tests.

The in-flight tests allow for the final assessment of the complex process of the aircraft construction. They are also an inseparable element occurring during the entire process of its operation.

For all these reasons, it is necessary to develop a decision model that will facilitate making of optimal decisions in order to perform a test flight, taking into account the reliability and safety of these flights.

It is assumed that the aircraft maintenance system exists, and the aircraft operation process is a two-state process.

Therefore, there are two states: *operation and maintenance* i.e., aircraft being in the unit perform specific tasks or stay in the maintenance system, if it results from the maintenance schedule. It is also assumed that the considered maintenance system has the number of aircraft in constant technical readiness resulting from the fixed number of tasks.

The development of such decision models requires the definition of *decision variables*, *constraints* and *a criterion function*.

The most important decision variables:

– certain maintenance types – a set of $O = \{1,2, \ldots, o, \ldots, O\}$, where $\boldsymbol{O}$ is the number of the maintenance types,
– a group of pilots of a given class, numbered with p variable, i.e. $P = \{1,2, \ldots, p, \ldots, P\}$, where: P - the number of available pilots that can perform a certain type of the test flight,
– a set of the numbers of the aircraft types: $\Omega = \{1,2, \ldots, \omega, \ldots, \Omega\}$, where: Ω – the last number of a given aircraft type.

However, the function criterion of the objective, which is a problem of the maintenance system optimisation, consists in its minimisation:

$$F = FW + FZ + FS \rightarrow min,$$

where:

FW – cost per time unit resulting from the necessity of replacing the worn aircraft (its elements) to new ones,
FZ – cost per time unit resulting from "freezing" the funds for the purchase of new aircraft (of a given type),
FS – cost per time unit resulting from maintaining of the maintenance system.

As it can be observed, it is basically the cost of the system functioning, which consists of the sum of three components. Owing to such a designated function of the objective, a concept of application (IT system for supporting the test flights) was developed under the name DOSPIL. Its implementation was mainly based on statistical, probabilistic, and mathematical logic methods. The database (created and presented on the basis of PHP and My SQL languages) is under constant development, due to the fact that it is updated with further new incidents and elements from the test flights.

During the computer implementation of the described (above) method – firstly, it was necessary to develop the algorithm for determining the schedule of projects related to the test flight.

The DOSPIL application covers the entire test flight performance system with its functionality. The main task of the application is to increase the efficiency of the aviation personnel management, mainly the personnel of test pilots.

The IT support system will (mainly) provide the supervisors with supervision over the test flights, as well as it will enable the effective safety and preventive action management by collecting information.

The numerical (computer) implementation of the method and its algorithm can be presented as in Fig. 5. The application server was divided into six basic tabs, owing to which it is possible to (smoothly and clearly) navigate the system. The application layer will allow for direct supply of the created database with information that will then allow for the creation of relevant statements and reports – previously defined by the user.

The application also includes the training of given personnel, which is described with the use of the appropriately prepared algorithms in order to achieve the required level of advancement.

The example algorithm for achieving the appropriate qualifications to obtain the 3rd class test pilot rating was presented in Fig. 6. The described DOSPIL application stores the entire history of operation of the test flight performance system. In addition, the DOSPIL IT tool is adapted to collect data related to daily functioning of the unit or the aviation organisation. The system collects data on the performed test flights, the incidents occurred during these flights, and at the same time, an inference module related to the necessary prevention measures was created. This module is used in order to implement preventive recommendations based on the aviation incidents collected in the system.

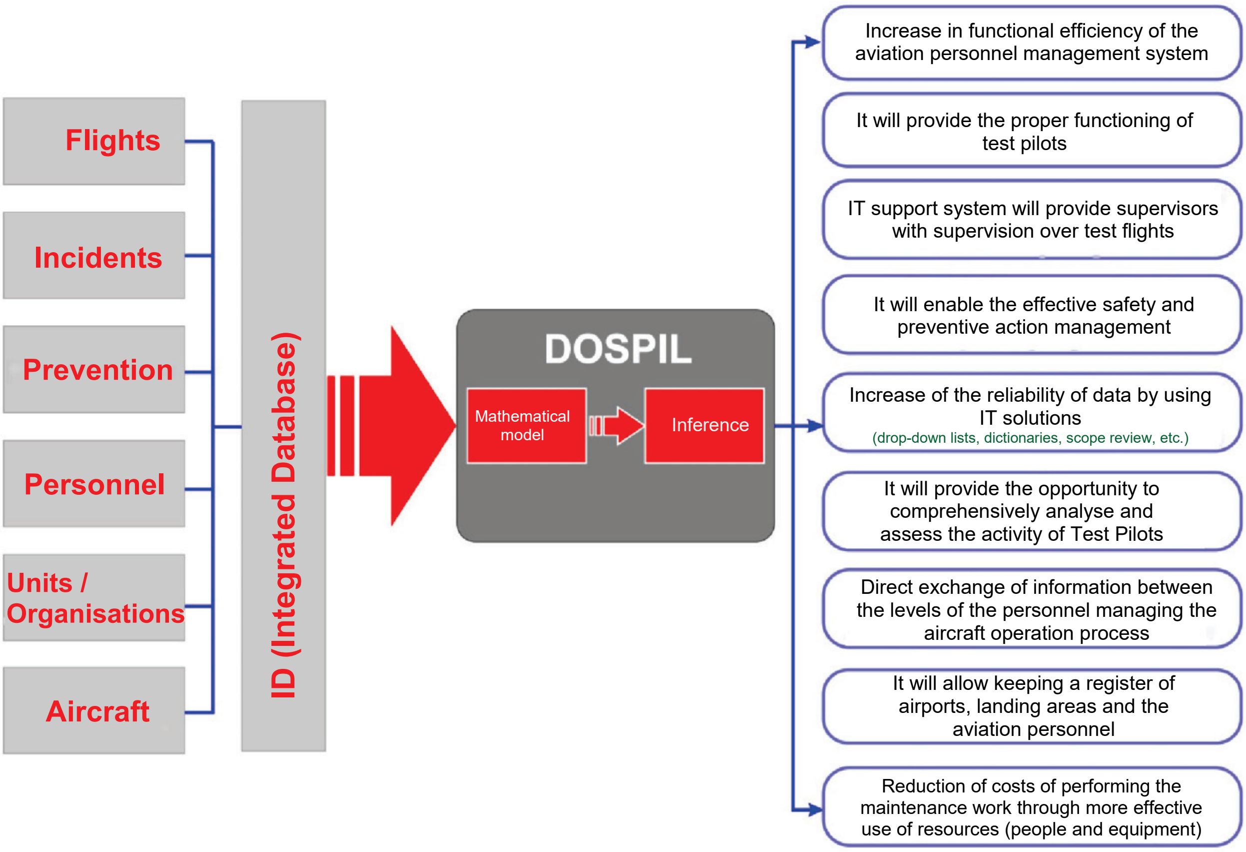

Fig. 5. Algorithm of the computer implementation of the DOSPIL system. Source: own development

3. Examples of the DOSPIL system application

The IT DOSPIL system allows entering all data related to the aviation personnel. However, it was possible to integrate this system with the IT flight safety support system, under the code name TURAWA, and the aircraft operation support system, SAMANTA. After clicking the "Plan" tab (Fig. 7) in the DOSPIL application, it is possible to choose the aircraft on which it is intended to plan the required test flight by the pilot.

The aircraft numbers are displayed in order of maintenance, which must be carried out as soon as possible. The colours introduced into the system are also to remind the user about the need to perform a given test flight and assigning a particular pilot to the aircraft type.

The red colour means that the planned flight falls within a period of less than 10 calendar days and it is important to assign the pilot, who meets the required criteria to perform a given flight type, to the aircraft number as soon as possible.

The orange colour means that the performance of a given test flight was planned within the next 30 days.

However, *green* means planning the flight for a period of more than 30 calendar days.

After selecting a given aircraft number, to which we want to assign a given pilot, the application takes us to the next window, in which there is a brief profile of the aircraft based on: aircraft version, side number, serial number, manufacture date, manufacturer, technical resources, total flying time, the number of landings, the number of repairs, the last repair date, place of repair, technical resources after the repair, the number of landings after the repair, and flying time after the repair.

The next window presents the result of assigning a given pilot to the selected aircraft and type in order to perform the test flight. The availability of the pilot is identified after counting all seven factors and taking into account the schedule of possible flights of a given pilot – see Fig. 8.

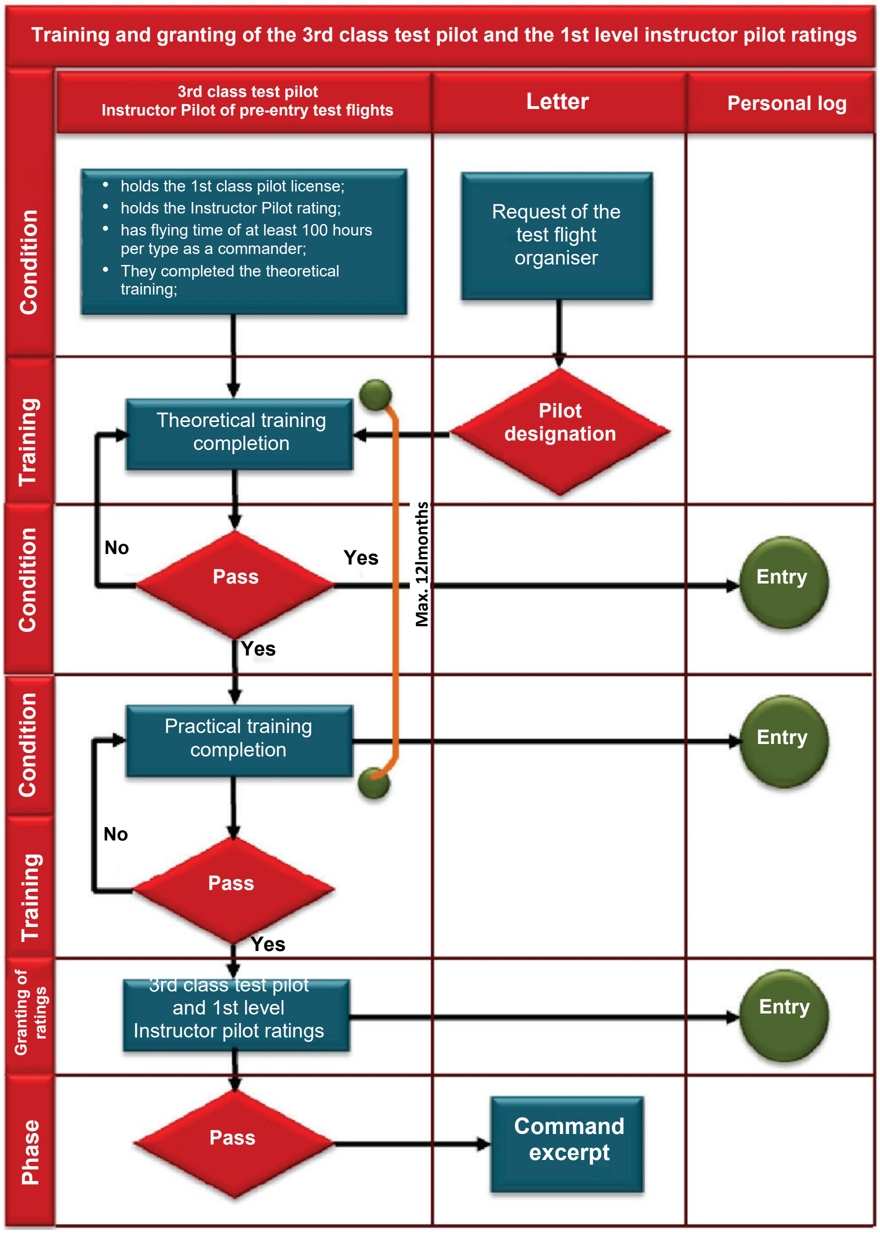

Fig. 6. Example algorithm of obtaining the 3rd class test pilot rating used in the DOSPIL system, source: own development

The green star allows choosing a given pilot and assigning the pilot to a given flight. The yellow star informs us that a given test pilot is close to exceeding the time limit for a given category.

A very important element of the DOSPIL system includes the statistics tab, where it is possible to conduct the reliability analyses. Fig. 9 presents an example of this analysis type for M28BP/T Bryza aircraft.

Another possibility of the described reliability analysis module allows, for example, for a percentage presentation of the number of failures that occurred on this aircraft, but for specific systems and installations. Fig. 10 presents an example of the number of the found failures for the selected, important avionic systems and those installed in the airframe – responsible for operation of the individual airframe and engine systems.

In the discussed reliability analysis module, it is possible to assess, e.g. the number of failures, the number of operated aircraft, etc. for the specific value of flying time or the number of another reference parameter (value). The reference parameter is basically "smooth" and dependent on the aircraft type (e.g. combat or transport).

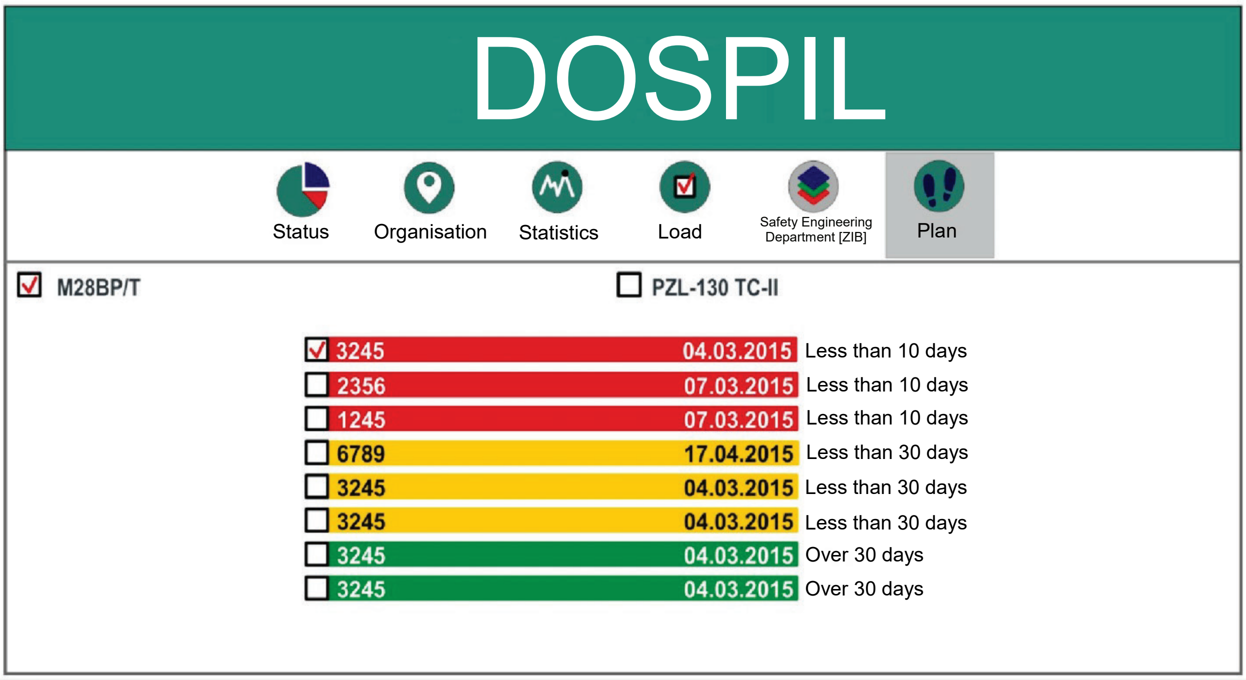

Fig. 7. Selection of the aircraft type in the DOSPIL system – example

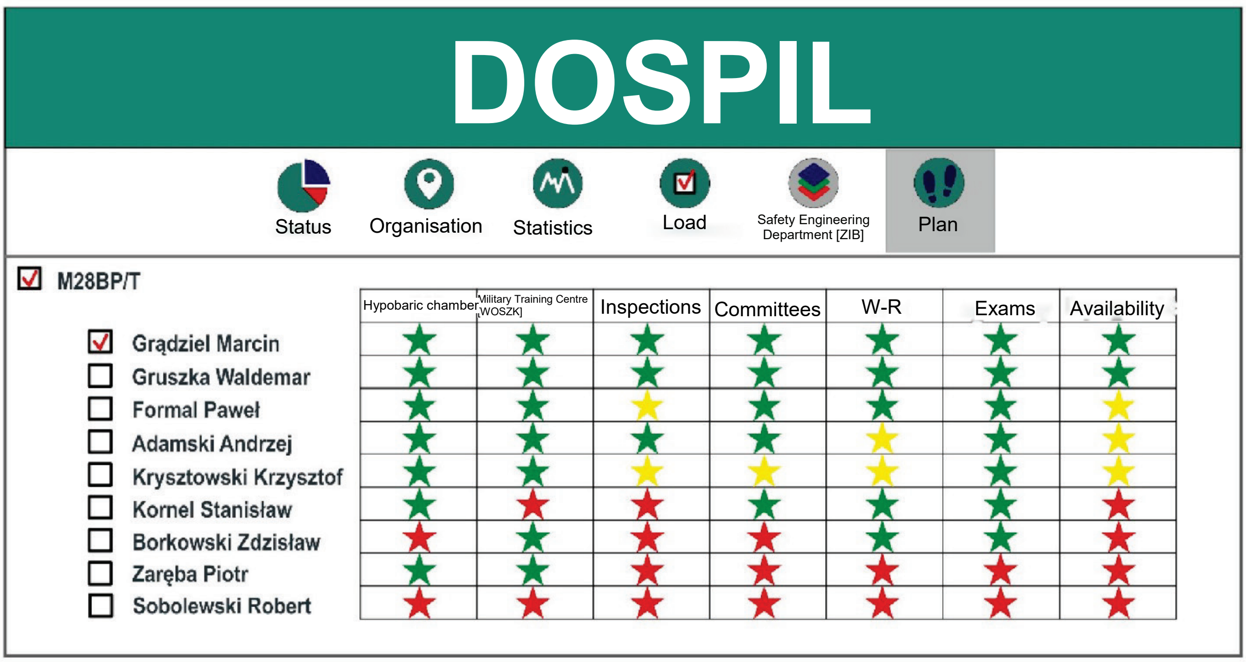

Fig. 8. Result of assigning the pilot to the aircraft and a given test flight in the DOSPIL system

Such analyses allow for early identification of unfavourable trends and early initiation of preventive measures raising technical and combat readiness of aircraft and the flight safety.

An important element regarding the risk taken during test flights is the proposal to introduce the so-called Risk Assessment Sheet (RAS) before performing the test flight. It includes the necessary data on the pilot, in-flight tests, the aircraft, the environment and management associated with a decision-making level (Tab. 1). On the basis of the obtained number of points, the probable risk is estimated (see Tab. 2).

The risk assessment sheet is useful not only in the process of estimating the risk of a single test flight, but also in the activities related to the broadly understood risk management in aviation.

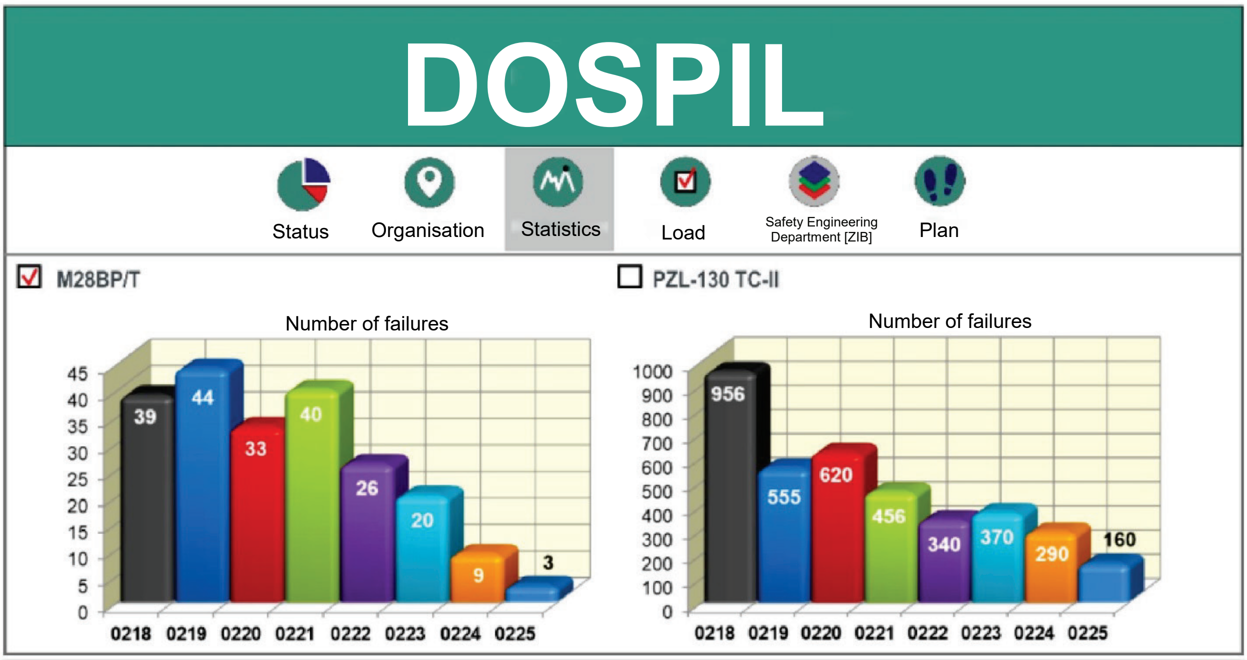

Fig. 9. Reliability analysis in the DOSPIL system – example

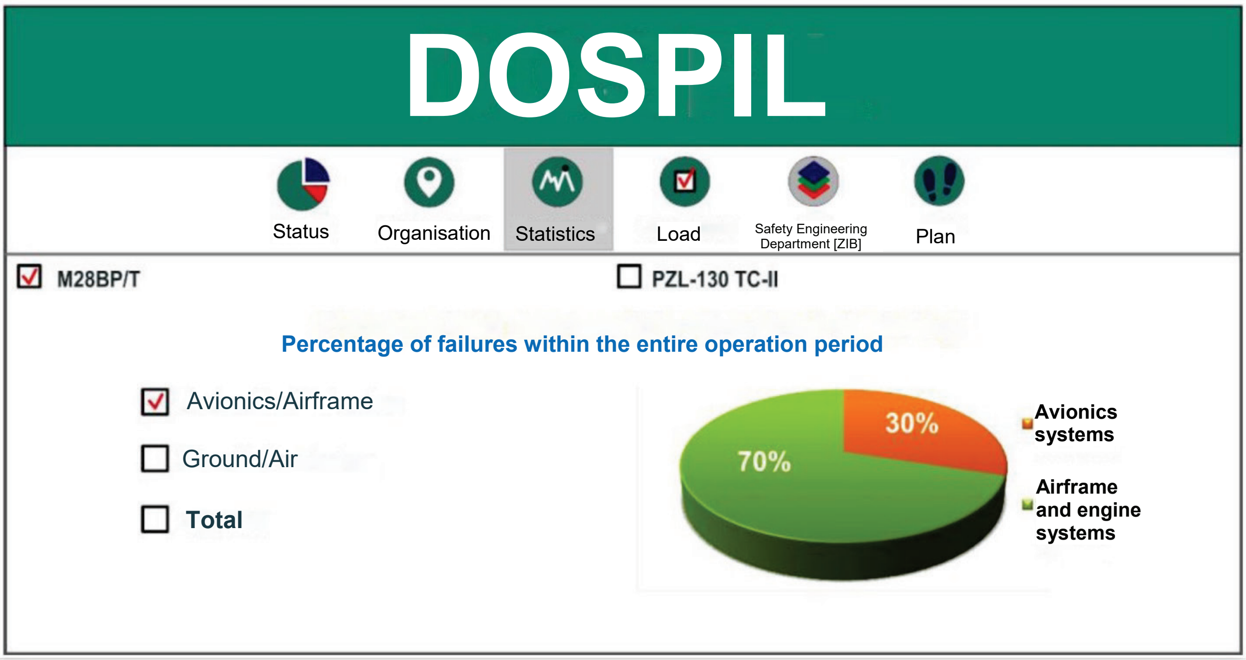

Fig. 10. The number of failures of avionics systems, as well as the airframe and engine systems on the M28BP/T aircraft from the beginning of operation – example

It includes the systemic solutions related to the decision-making level gradation in accordance with the principle "the higher the flight risk level, the higher the decision-making (command) level that is entitled to accept and decide on its implementation".

4. Summary and conclusions

The article indicates that the efficiency of the aircraft operation must be supported by in-depth analyses of the obtained expenditure to the incurred one mainly related to maintaining of the maintenance system, the performance of test flights and conducting of the research. In addition,

Tab. 1. Risk Assessment Sheet – example

ITEM	ENTITY	LOW RISK LEVEL	P	MEDIUM RISK LEVEL	P	HIGH RISK LEVEL	P
PILOT							
1	Experience	> 500 hours	0	500-200 hours	2	< 200 hours	4
2	Test flight date	< 1 week	0	1-2 weeks	1	> 2 weeks	4
3	Test flight type	Pre-entry 3rd category	0	Pre-entry 1st and 2nd categories	2	Test flight	4
4	Rest of the crew	> 11 hours	0	8-11 hours	2	< 8 hours	4
5	Human factor	Normal situation	0	In-flight test performance for the first time	3	Bad psychophysical condition	6
IN-FLIGHT TEST							
6	Check-in before the flight	1 hour before the flight	0	Check-in on the previous day	3	No check-in (1)	6
1	Change of the test pilot	None	0	Yes > than 3 hours before the planned flight	2	Yes < than 3 hours before the planned flight	6
8	Another flight on a given day	the first	0	the second	2	the third	4
9	Take-off delays	< 1 hour	0	1-2 hours	2	> 2 hours	4
AIRCRAFT							
10	Weight for take-off	< 70% max. weight	0	70-80% max. weight	2	> 80% max. weight	4
11	Weaponry	None	0	Gun	2	Bombs, rockets, gun	4
ENVIRONMENT							
12	Visibility	> 8 km	0	5-8 km	2	< 5 km	4
13	Cross wind	< 10 kts	0	10-20 kts	4	> 20 kts	6
14	Dangerous weather phenomena, e.g. storms/icing	Weak	1	Medium	4	Strong	6
15	Knowledge of the take-off and landing airports,	Many times	1	< 3 times	1	For the first time	4
16	Airport equipment and systems that support landing	Hooks Barriers, ILS/DME, PAR	0	VOR, TACAN, NDB	2	None	6
17	Clouds (in' the area of tests)	BKN-OVC > 5000 feet	1	BKN OVC 5000-2000 feet	3	BKN OVC< 2000 feet	6
18	Wind (in the area of tests)	< 20 kts	0	20-30 kts	2	> 30 kts	4
MANAGEMENT							
19	Decision-making level / Acceptance of flight	Manager of tests / Test pilot	1	Flight organiser	2	Flight manager	3

Tab. 2. Probable risk assessment

POINTS	RISK	RISK: ………………
< 9	SMALL	PILOT INDEX: ………….
10-18	MEDIUM	DATE ………………………
19-25	HIGH	Instructor Pilot of test flights: ……………………
> 25	VERY HIGH	Manager of tests: …………….

the operational test flights of aircraft require the development of a model (system) to secure the flights with the increased safety requirements. At the same time, it was indicated that one of the tools of the systemic solutions for the risk assessment, e.g. of test flights, can be the so-called risk assessment sheet. It is a simple tool that allows to estimate the risk level during the in-flight tests based on the previously defined risk factors, which may occur during their implementation, and to have a major impact on the flight course. However, this solution has its opponents, especially among decision-makers, due to the necessity of approving own activities by the superior level. Such a state, in which the decision of the task implementation is not within the limits of own competence, results in a lack of trust and uncertainty, and it extends the entire decision-making process. Hence there was a great need to look for other solutions that can reduce the risk of the planned mission to the level at which the decision-making process in only the responsibility of a person performing the test flight.

The basic elements of the decision model of reliability and safety of the test flights, presented in the article, constitute an attempt to solve the above-mentioned issue, where the main features of the aircraft, which are examined during the test flights, were described.

The model for maintaining the aircraft that perform the test flights, where the most important boundary conditions were explained with the use of the essential mathematical methods, was also developed. It allows to quite precisely determining the maintenance times, the maintenance system performance, the selection of crews, etc. The importance of the correctly developed and presented algorithms, on the basis of which it is possible to effectively assess the reliability and safety of the test flights, was demonstrated. On the basis of the above algorithms, the elements of the system for supporting the aircraft maintenance decision and the flight performance – under the code name DOSPIL, the main task of which is to support the supervision of test flights, were graphically developed and presented. The examples of the DOSPIL system operation – presented in the article – confirm its high effectiveness in assigning the crew to the appropriate task performed during the test flight.

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