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SELECTED ASPECTS OF TECHNICAL READINESS RELATED TO THE EXPLOITATION SYSTEM OF TRAINER AIRCRAFT IN MILITARY AVIATION

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Abstract

One of the problems becoming increasingly important in the exploitation process of each technical object is effectiveness expressed as a ratio of the value of obtained results to the related expenditure. There are several criteria to evaluate the effectiveness of the exploitation process. However, in their selection, it is necessary to take into account the characteristics not only connected with a concrete object or system, but also with a model of its use. In civil aviation, especially in case of airlines and various kinds of service companies, the effectiveness of exploitation system of the aircraft fleet is assessed primarily in economic terms. However, in military aviation, due to its characteristics, slightly different criteria must be applied. In practice, the effectiveness of such systems is usually assessed based on the index of technical exploitation readiness, which specifies the system readiness to execute the agreed tasks within predetermined time.

This paper presents selected aspects of technical readiness related to the exploitation system of trainer aircraft in military aviation. The issues connected with determining the total flying time, conducted within the framework of the training cycle, are discussed. The factors affecting the state of technical readiness related to the exploitation system of the aviation technology as well as methods for determining the required number of aircraft to perform the tasks planned for a given period and the index of available service life resources.

Keywords: *technical readiness of aircraft, aviation training system, technical exploitation system*

1. Introduction

The technical exploitation of an aircraft is most often defined as a set of activities, actions and work carried out on the ground by the technical service in order to maintain the required level of its technical suitability and airworthiness, and thereby its safe use as intended [5].

One of the most important factors of the exploitation process is its effectiveness, which is determined by the level of use of the exploitation potential of a given object or system. In the broad sense, the concept of effectiveness is to achieve the best possible results at the lowest expenditure incurred. Thus, the exploitation system of aircraft is effective if it allows the execution of a given task at the lowest possible expenditure.

There are several criteria, which allow us to evaluate the effectiveness of the exploitation process. However, in their selection, it is necessary to take into account the characteristics not only connected with a concrete object or system, but also with a model of its use [1]. In practice, slightly different criteria will be used to assess the effectiveness of exploitation system of the production machinery, rolling stock or air fleet.

In civil aviation, especially in case of airlines and various kinds of service companies, the effectiveness of exploitation system of the aircraft fleet is assessed primarily in economic terms, i.e. on the basis of the relationship between the results obtained from operating expenses and the expenditure incurred for this purpose. For obvious reasons, the effectiveness of the planes and helicopters' exploitation system in military aviation is assessed on the basis of slightly different criteria. It should be emphasised that in military aviation a subject matter of the effectiveness' assessment of exploitation system looks different than in case of combat, transport or trainer aviation. The tasks set for different types of aviation are in fact different from other criteria for the effectiveness' assessment of their performance. Thus, it is a problem covering a wide range of different and quite complex issues. Therefore, this article is limited to the discussion of selected aspects related to the assessment of technical exploitation system of trainer aircraft in military aviation.

2. Tasks performed by the exploitation system of aircraft in trainer aviation

While carrying out the analysis concerning the subject matter related to the effectiveness of each exploitation system, it is essential to define the tasks performed by the given system. In case of the exploitation system of aircraft fleet in trainer aviation, the main objective is to secure the required flying time on various types of planes or helicopters in a given training cycle. Unlike other types of aviation, this task is relatively easy to define and schedule.

The required flying time on a specific type of aircraft in a given training cycle is calculated on the basis of the applicable aviation-training programme and the planned number of students. Furthermore, it is necessary to include the additional flying time resulting from the need of a possible increase of time provided in the programme for mastering specific exercises and resuming habits after a break in the performance of flights, which exceeds mandatory standards. Apart from this, it is essential to plan the flying time required for training and pilot instructors training, technical test flights of the exploited aircraft (after the performance of periodic work of a higher order, the change of key units, e.g. aircraft propulsion system), and also for the possible flights related to the performance of other tasks. In case of conducting the analysis concerning the required flying time on the stage of creating the fleet of a given type of aircraft, it is important to assume the maximum number of students foreseen for training in the future.

The total flying time required in a given training cycle – $\sum \mathrm{T(Lot)}$ – will be:

$$\sum \mathrm{T(Lot)} = \mathrm{L(s)} \cdot [\mathrm{T(p)} + \mathrm{T(d)}] + \sum \mathrm{T(in)} + \mathrm{T(t)} + \mathrm{T(i)}, \quad (1)$$

where:

- $L(s)$ – the number of students,
- $T(p)$ – flying time provided in the aviation training programme,
- $T(d)$ – additional flying time provided for one student (the revision of not sufficiently mastered exercises, habits' resumption),
- $\sum \mathrm{T(in)}$ – total flying time of the instructors according to their individual training plans,
- $T(t)$ – flying time planned for technical test flights,
- $T(i)$ – flying time planned for the performance of other tasks.

The aviation-training programme, especially at the initial stage, provides for the performance of a significant number of short flights near the airport. In such cases, in the process of tasks planning for the aircraft fleet, the expected number of landings should also be taken into account. Moreover, – if necessary – the plan should also specify the necessity concerning the on-board weapon systems, e.g. the expected number of shots from guns or unguided missile launchers. A very important part of planning is to develop a rough timetable for the implementation of individual tasks. It will allow the assessment of the degree of their accumulation in a given period of time. However, it is important to be aware of the fact that the actual timetable of flights, in practice, often deviates from the planned one. This is due to a number of factors, on which the organizer of the training has no impact. They include, among others, unsuitable weather conditions, indisposition of a student or an instructor pilot, failure of equipment, or temporary exclusion from the airport exploitation. In turn, the delay caused by these factors cannot be easily levelled due to the standards of maximum flight time in one day, which apply to both the student and the instructor.

The plan prepared in such a way for a specific aviation training cycle constitutes a basis for the formulation of definite tasks for the exploitation system of aircraft.

3. Technical readiness of the exploitation system of aircraft

A variety of factors, the most important of which is reliability, influences the effectiveness of the exploitation system of a technical object. In the international terminological standard, it is defined as “a combination of properties that describe the object's readiness as well as indestructibility, maintainability and providing the means of use, which influence it”. According to this definition, the problem of reliability should be analysed not only in terms of a single object, but also of its whole exploitation system. In accordance with the reliability theory, the effectiveness of the exploitation system is most often assessed on the basis of the technical readiness of exploitation – K_g (t). It determines the readiness of the system for the performance of agreed tasks within predetermined time and is defined according to the following formula [6]:

$$K_g(t) = \frac{E\,(T)}{E(T) + E\,(\Theta)}, \tag{2}$$

where:

E(T) – the expected value of random variable of the time of airworthiness of an object,
E(Θ) – the expected value of random variable of the time of non-airworthiness of an object.

A simplified form of the above formula is used for practical calculation [6]:

$$K_g = \frac{T_z}{T_z + T_{nz}}, \tag{3}$$

where:

T_z – the average time of the object (system) being in a state of airworthiness,
T_{nz} – the average time of the object (system) being in a state of non-airworthiness.

A state of technical (functional) readiness of the exploitation system includes a set of such exploitation conditions, the aircraft of which are airworthy in a given moment in terms of reliability, have material, energetic and informational resources necessary to operate, and are in a designated area. The states of technical readiness are the exploitation states, in which the utility potential did not exceed the limit values that allow operating properly [4].

A number of factors, the most crucial of which are properties, technical service system and logistical security system, influence a degree of the technical readiness related to exploitation system of a given type of aircraft. For example, the analysis of technical readiness of the SH-2G helicopter during the 30-days mission makes it possible to estimate its level, and thereby to assess the effectiveness of the used operational system – Tab. 1 [6]. According to the comparison, it can be seen that only less than 7% of the state was allocated for the active flight performed by a crew, and waiting for use exceeds 70% of the time.

Among the features, which are characteristic of the aircraft, durability and reliability, as well as the exploitation susceptibility, maintainability, the ability of diagnosis, repairability, renewability, and the ability of renovation are those, which have the most significant effect on its technical readiness.

Tab. 1. The assessment of readiness state of the SH-2G helicopter during the 30-days mission (720 hours) [6]

The exploitation status	Percentage participation of time of the helicopter being in this state in [%]
performance of the pre-flight operation	4.17
performance of the start operation	3.61
duty (waiting for use)	72.78
active use by the crew	6.94
refuelling	0.69
performance of the special operation	11.39
performance of the corrective operation (renovation)	0.42

Durability of the aircraft or its units is understood as a permissible period of their use, in which they retain the features and technical parameters in accordance with the applicable requirements and standards. The durability depends primarily on the fatigue strength of construction, wear of the tribological nodes, metal corrosion, delamination of the composites, or destruction of the non-metallic material [3]. A permissible period of use of the aviation equipment, colloquially called the technical service life resources, is determined in flight hours, working hours of the aircraft propulsion system, or operation cycles expressed, e.g. by the number of landings, or the number of shots from the barrel weapons or firings from the missile launcher. Furthermore, both the aircraft itself and many of its units and devices have the specified permissible period of use, the so-called calendar service life resources. A period of use between successive repairs is called the service life resources between repairs. Both the total service life resources and the service life resources between repairs are verified in the exploitation process, and on the basis of the results of conducted research, they may be extended, or in some other cases, shortened.

The service life resources between repairs have a direct impact on the index of technical readiness of exploitation. Therefore, it is desirable that both the technical service life resources between repair and the calendar service life resources between repairs of the aircraft were as long as possible, and the service life resources of units and on-board equipment were as much as possible the same as the airframe's service life resources.

In common with the durability, the aircraft's reliability, related to the frequency of malfunctions and defects, has a significant impact on the technical readiness of the aircraft. In practice, the level of reliability is most often determined with the MTBF (Mean Time Between Failures) index. However, for the purpose of assessing the technical readiness, the most useful parameter is the total time of when the object is staying in a state of non-airworthiness, due to malfunction or damage within the considered period – $\sum T_{nz}(N)$. It includes the total time from the moment of disclosure of the state of non-airworthiness until it is restored to an airworthy condition, i.e. time of the diagnosis, waiting for repair and its implementation, and the conduct of the required control tests (e.g. the test flight, the aircraft propulsion system test, etc.). While conducting the analysis of the reliability of the aircraft, it should be remembered that its level is not a constant value and is subject to change in the exploitation process. Moreover, it also depends on a number of additional factors such as the level of technical service and its organisation, environmental conditions, etc.

The technical service system, understood as a set of activities carried out by the technical services in accordance with applicable rules and standards, in order to maintain its suitability to perform the aviation tasks, [4] is another factor which significantly influences the readiness of exploitation system of a given type of aircraft.

Currently, both in civil and military aviation, the maintenance of the aircraft's airworthiness are performed based on the following strategies:

- exploitation according to the service life resources (the exploitation potential),
- exploitation according to the technical condition,
- mixed system,
- exploitation according to the level of reliability,
- exploitation according to the effectiveness.

The exploitation system in accordance with the service life resources is a cyclical performance of the assumed scope of activities assigned to a specific level of the technical service or renovation (repair), after the use of the authorized period of use expressed in flight hours, hours of operation (e.g. of the aircraft propulsion system), the number of cycles (e.g. landings), or after a certain period of exploitation.

Dates and scopes of the particular levels of services and repairs are determined on the basis of results of the evidence research, and then verified based on the many-year exploitation experience.

In the past, the exploitation according to the service life resources was a commonly applied strategy of use of both the military and civil aircraft. At present, it is mainly used in relation to the older generation of planes and helicopters. Its main disadvantage is the need for performance of the applicable level of services, regardless of the current technical state of the exploited object. In addition, it requires careful planning of the exploitation intensity of the entire fleet of a given aircraft type in order to prevent the cases of simultaneous withdrawal of many units, due to the need to comply with the applicable technical services or repairs [2].

The exploitation system in accordance with the technical condition involves constant monitoring and predicting the technical condition of the exploited object as well as taking preventive actions, technical services, repairs or renovations, if necessary [2]. This type of strategy is increasingly being used in modern aircraft construction. They are equipped with more or less complex on-board and ground-based diagnostic systems, which allow a quick assessment of the technical condition of specific units, systems and circuits of the aircraft, including the flight. The computer subsystem, which collects and processes the acquired data, and then presents the results of their analyses, is often an additional element of the diagnostic system. An important advantage of this strategy is the ability to use the full exploitation potential of each exploited object. However, its limitation in aviation is the fact that it can be applied only in case when methods and means of diagnostics allow the prevention exceeding the limit states [5].

The mixed exploitation system constitutes a combination of the two aforementioned strategies. It is used mainly when the object is exploited according to the service life resources; whereas it is selected systems or units are exploited according to the technical condition, or the other way around.

The exploitation system in accordance with the reliability is based on taking the exploitative decisions based on the results of periodic inspection of an object (device) exploited until the occurrence of an increased intensity of damage. This strategy can be applied only when the consequences of damage do not violate safety rules and do not significantly increase the exploitation costs.

Currently, the effectiveness criterion is also more often taken into consideration in the exploitation process. Due to the very dynamic technological progress observed in the recent years, more frequently there arises the problem concerning the advisability of further use of the equipment which, although still has the exploitation potential, no longer meets the current requirements of the user or is not sufficiently effective and competitive. For this reason, a number of older machines in aviation are withdrawn, or they are often subjected to the process of a very precise modernisation.

The type of the adopted strategy of the aircraft exploitation has a direct impact on their technical readiness. It affects, in fact, the system and frequency of the performance of technical services, the method of assessment and predicting the technical condition, as well as periods of the aircraft operation and its individual units and devices. In military trainer aviation, the exploitation system in accordance with the service life resources or the mixed system are applied.

Regardless of the adopted exploitation strategy, vital factors in the technical service system of aircraft are: the organisational structure of technical services, the level of theoretical and practical preparation of the service personnel, the quality of the descriptive-exploitative documentation, the exploitation computer systems, including exploitation database, and also the technical facilities (infrastructure, tools, ground-based diagnostic systems, the measurement and control apparatus, etc.). The importance of the exploitation planning system and logistical security system, which is responsible for the material and technical supply, including the timely delivery of spare parts, should not be ignored. In turn, the proper exploitation planning allows a rational use the technical and calendar service life resources of an individual aircraft. Additionally, it makes it possible to avoid the accumulation of deadlines of the periodic work's performance of a higher order or repairs, and also provides continuity of the material and technical supply, including the supply of spare parts in the projected dates. As a result, both the planning and logistics system significantly affect the period of when an individual aircraft stays in a state of non-airworthiness, due to waiting for the repair, technical services and repair.

In order to assess the technical readiness index $K_g(t)$ of the exploitation system of a specific aircraft type during the period provided for the implementation of training cycle, one should define the total time in which the individual units of planes and helicopters will be excluded from operational use. The reasons for their exclusion include the need for the performance of technical services, repairs, and change of parts and units for which the specified permissible period of use expires, as well as for the removal of any malfunction and the performance of unplanned repairs. The total number of days of exclusion of the operational readiness of a single aircraft $T_{N(x)}$ will be:

$$T_{N(x)} = \sum T_{N(o)} + \sum T_{N(w)} + T_{N(r)} + \sum T_{N(u)} + \sum T_{N(n)}, \quad (4)$$

where:

$\Sigma T_{N(o)}$ – the total number of days foreseen for the performance of technical services,
$\Sigma T_{N(w)}$ – the total number of days foreseen for the change of parts and units,
$T_{N(r)}$ – the total number of days foreseen for the performance of repairs,
$\Sigma T_{N(u)}$ – the total number of days foreseen for the removal of malfunctions,
$\Sigma T_{N(n)}$ – the total number of days foreseen for the performance of repairs.

The index of technical exploitation readiness of a given unit of aircraft $K_g(SP_x)$ may be calculated in accordance with the following formula:

$$K_g(SP_x) = \frac{T_{SZ} - T_{N(SPx)}}{T_{SZ}}, \quad (5)$$

where:

T_{SZ} – duration of the aviation training cycle in days,
$T_{N(SPx)}$ – the number of days during which an individual aircraft stays in a state of non-airworthiness, in the duration of the aviation training cycle.

Having the technical readiness indexes of the exploitation system of each unit of aircraft at the disposal, it is possible to determine the corresponding index for the entire fleet $K_g(F)$. However, in military aviation, this parameter is not very useful, as it does not sufficiently define the technical readiness of the exploitation system of the aircraft fleet to perform the assumed task in the individual time periods. It is important to remember that the index determined in this way $K_g(F)$ in the following training cycles will undergo changes, and often very large ones.

The performance of assessment of a specific exploitation system of the aircraft to secure a specific aviation training cycle requires an analysis of at least a few parameters. The first step is to determine the index of available service life resources $R_h(F)$ calculated according to the formula:

$$R_h(F) = \frac{\sum T(Lot)}{\sum R_h(F)} = \frac{\sum T(Lot)}{R_h(SP_1) + R_h(SP_2) + R_h(SP_3) + \cdots R_h(SP_x)} \leq 1, \quad (6)$$

where:

$\Sigma R_h(F)$ – the total available resource (time of flight) of the fleet constituting the sum of resources of an individual aircraft,
$\Sigma T(Lot)$ – the total dimension of flying time planned for the performance in the duration of the training cycle, calculated according to the formula (1).

This index informs if the available service life resources are sufficient for the performance of the assumed task. Theoretically, it can reach a value of 1, but in practice it should always be lower due to the possibility of unforeseen events, which cause the unplanned turn of a number of aircraft into the state of non-airworthiness. In justified cases, this index may also be determined for other parameters such as the number of landings or the number of firings of missiles.

However, the discussed parameter does not indicate if the available service life resources will make it possible to perform the tasks provided for the training programme at any time of its implementation. For this purpose, it is necessary to develop a timetable presenting the planned flying time as well as the available exploitation potential in a given day or week of the training cycle. Moreover, this plan should allow for the possible restrictions concerning the maximum duration of flights' round in a given day. In case of one-shift operation, this time might be, for example, 8 hours.

In developing this timetable, the following correlation may be helpful:

$$\mathrm{DT_{LOT}} + \sum \mathrm{DT_{PRL}} + \sum \mathrm{DT_{OT}} \leq \mathrm{L(SP)} \cdot \mathrm{T_{ZM}}, \tag{7}$$

$$\sum \mathrm{DT_{PRL}} = \sum \mathrm{DT_1} + \sum \mathrm{DT_2} + \sum \mathrm{DT_3} + \sum \mathrm{DT_4}, \tag{8}$$

$$\sum \mathrm{DT_{OT}} = \sum \mathrm{DT_{PL}} + \sum \mathrm{DT_{ML}} + \sum \mathrm{DT_{POL}}, \tag{9}$$

where:

$\sum \mathrm{DT_{LOT}}$ – the total flying time planned in a given day,
$\sum \mathrm{DT_{PRL}}$ – the total time of additional airport procedures,
$\sum \mathrm{DT_{OT}}$ – the total time of technical services of aircraft (SP) taking part in flights in a given day,
L(SP) – the number of SP taking part in flights in a given day,
$\mathrm{T_{ZM}}$ – the duration of flights' round in a given day,
$\sum \mathrm{DT_1}$ – the total duration of the SP start-up process before the flight,
$\sum \mathrm{DT_{2(3)}}$ – the total duration of taxiing procedures for the take-off (after landing),
$\sum \mathrm{DT_4}$ – the total duration of the SP shut-down procedures after the flight,
$\sum \mathrm{DT_{PL}}$ – the total performance time of the SP pre-flight operation taking part in flights in a given day (including their move to the apron),
$\sum \mathrm{DT_{ML}}$ – the total time of recreation of readiness for the next SP departure taking part in flights in a given day,
$\sum \mathrm{DT_{POL}}$ – the total performance time of the SP post-flight operation taking part in flights in a given day (including their move to the apron).

The required number of aircraft to perform the aviation task planned for a given day is then:

$$\mathrm{L(SP)} \geq \frac{\sum \mathrm{DT_{LOT}} + \sum \mathrm{DT_{OT}}}{\mathrm{T_{ZM}}}. \tag{10}$$

The example of planning of the aviation technology's involvement in the performance of the assumed aviation tasks is presented below in Tab. 2 and Fig. 1. It should be emphasised that the number of technical flights is not always consistent with the number of performed flights. The term “technical flight” stands for the exploitation cycle of an aircraft which begins at the apron, from the start-up of the aircraft propulsion system and ends with the switch-off after the flight, on the apron.

For these reasons, in case of successively performing several flights without the necessity of taxiing to the apron (e.g. flights around the circle, or in case of helicopters, flights to perform a hover close to the ground), the flights are treated as one technical flight.

Tab. 2. The weekly table of aviation technology involvement

Day of the week	1	2	3	4	5
Total number of technical departures	45	60	70	60	50
Total time of flight (hour : min.)	15:00	15:00	17:30	30:00	33:20
Total time of airport procedures	07:30	10:00	11:40	10:00	08:20
Total time of technical services	22:30	30:00	35:00	30:00	25:00
Total time of flights and technical services	45	55:00	64:10	70:00	66:40
Theoretical number of SP	7.5	9.17	10.69	11.67	11.11
Planned number of SP	9	10-11	12	13	12-13

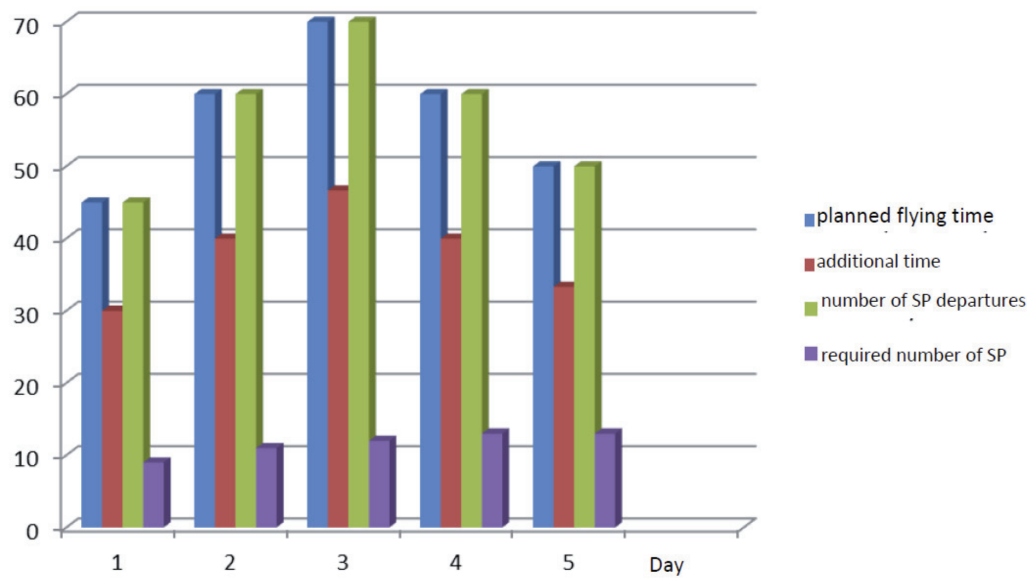

Fig. 1. The weekly timetable of aviation technology involvement

4. Conclusions

Technical readiness of the equipment has always played a key role in military aviation. Currently, even greater attention is paid to this subject matter, mainly due to the decreasing number of available aircraft, because of the increase of useful resources and constantly rising costs, both of their acquisition and target exploitation.

The problem of technical readiness of a particular type of aircraft should be considered not only through the prism of a single plane or helicopter but the entire exploitation system of a given fleet. A number of factors, a part of which depends on the manufacturer and the other part on the user, influence a degree of the technical readiness related to exploitation system of the aviation technology.

A designer and manufacturer have a decisive impact on the durability and reliability of the produced aircraft as well as its exploitation susceptibility, maintainability, the ability of diagnosis, repairability, renewability, and the ability of renovation. Moreover, to some extent, they also affect the exploitation system (preparation of the descriptive-exploitative and renovation documentation, defining the levels, scope and frequency of technical services and repairs), as well as the logistical security system (supply of spare parts).

In contrast, the user has a significant impact on the organisation and functioning of the technical service system and the logistics system. The user, in fact, decides on the organisational structure of technical services, the planning system of exploitation process, the level of theoretical and practical preparation of the service personnel, implementation and the method of using exploitation computer systems, including exploitation database. Furthermore, the user also has an influence on the shape of infrastructure, the level of technical facilities and the efficiency of the logistics system functioning, which is responsible for the timely performance of the material and technical supply, including the supply of spare parts.

All these mentioned factors, to a greater or lesser extent, influence the level of technical readiness of a given exploitation system of aircraft. The degree of their influence is dependent on the type of aircraft and its tasks, as well as the conditions connected with its exploitation. Therefore, in order to assess the state of readiness of the concrete exploitation system of a given aircraft, it is necessary to conduct a thorough and comprehensive analysis. Its results will make it possible to assess the degree of influence of each factor on the technical readiness of the examined exploitation system of aircraft, and then to take any action in order to reduce their negative impact, and consequently to increase the total period of the airworthiness of the aircraft fleet in the considered period.

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