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MODEL OF THE TACTICAL AIRCRAFT OPERATING SYSTEM AS AN AGGREGATED ANALYSIS DOMAIN FOR HAZARD RISK MANAGEMENT PROCESSES

Summary. The Tactical Aircraft Operating System (a system for tactical aircraft operational usage) constitutes the main research area of this paper. The authors present this system via an innovative model for an anthropotechnical system in the format of an aggregated analysis domain. This model constitutes a detailed explication of a fragment of the existing Tactical Air Force System metamodel at the level that concerns tactical aircraft operation systems. The aggregated analysis domain for tactical aircraft operations is built on seven single-analysis domain, each of which includes a series of processes, operations and events, related to the airman's aviation activities cycle, what happens during an air mission and when an aircraft operating cycle is carried out. The subsequent individual analysis domains are connected to each other by an airman-aircraft anthropotechnical pair. The introduced method of modelling the Tactical Aircraft Operating System ensures the desired generality, comprehensiveness, coherence and transparency of such a model, which allows for its implementation in various types of tactical aircraft and tactical air force bases. In principle, within

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the presented considerations, the model is described in relation to a single aircraft operating cycle, which is carried out by one airman during a single air mission. However, the authors have taken care when creating this model structure, so that its implementation in more complex aircraft operating cycles (more than one aircraft and one airman) is possible. Apart from the analysis domains ("before take-off", "departure", "air task", "arrival", "after landing"), which are closely related to the essential aircraft operations, the model also includes the analysis domains associated with air mission preparations and summaries. The model for the Tactical Aircraft Operating System is described by the authors in textual form, as well as in tabular form. The presented concept constitutes an attempt to formally notate the Tactical Aircraft Operating System model, in which each of the individual analysis domains can be treated as an area of interest for hazard risk management processes within the Tactical Air Force System.

Keywords: tactical air force; Tactical Air Force System; Tactical Aircraft Operating System model; aggregated analysis domain; hazard risk management

1. INTRODUCTION

The fast progressing development of both civil and the military aviation [20] has meant that the issues concerning aircraft operation [13,14] is becoming increasingly significant. This state of affairs has prompted the evolution of the basic components of aircraft operation systems, i.e., aircraft operating systems (aircraft operational usage) and aircraft maintenance systems [13,14]. The systemic approach to the operation of aircraft has attracted an increasing number of supporters in both civil and military aviation. New challenges and constant developments in science within the scope of aircraft operation systems, which is considered as an interdisciplinary field of human activity, continuously determine the need to implement new, clear, coherent and adaptive perceptions about components of aircraft operation systems and the relationships that exist between them. Therefore, it is justifiable to make an attempt to formally describe these components, which are necessary for various types of analyses. Such a description allows us to create models that may be more or less developed. It may also describe the actual components of aircraft operation systems more or less accurately. The main purpose of these models is to capture the essence of aircraft operations (operational usage) and maintenance systems. Whereas the modelling of these systems should be considered as processes that allow us to examine the relationships existing in and between these systems in terms of the entire aircraft operation system model in a given organizational unit, such as the Tactical Air Force Base (TAFB).

The main purpose of the following paper is to present the innovative concept of creating a model of the Tactical Aircraft Operating System (TAOS), which is one of the integral systems in the overall systems for tactical aircraft operations. The following considerations are based on the Polish Tactical Air Force [20], which is treated as an example of a tactical air force. It is assumed that the TAOS is an anthropotechnical system, which constitutes a detailed development of one part (Level 3) of the Tactical Air Force System (TAFS) metamodel. Level 3 of the TAFS metamodel concerns all the systems involved in tactical aircraft operations. The main assumption of the following concept is to present the TAOS in an innovative format of an aggregated analysis domain. The aggregated analysis domain of the TAOS consists of seven disjointed, individual analysis domains, which are ordered in time. Each of the analysis domains constitutes a sequence of processes, which integrate specific operations and events related to an airman's aviation activities cycle (AAAC). The subsequent individual analysis domains are connected to each other via an airman-aircraft anthropotechnical pair. Afterwards, each of the analysis domains will constitute a scientific area of research within the scope of processes that concern hazard risk management [1,7,8,16] in the TAOS. The assessment of hazard risks in each of the single analysis domains will finally lead to the comprehensive assessment of hazard risk in the entire TAOS. In principle, within the presented considerations, the TAOS model is described in relation to the single aircraft operating cycle, which is carried out by one airman during a single air mission (AM). However, the authors took care when constructing the model so that it can be implemented in more complex aircraft operating cycles, which often occur in practice. The model presents the TAOS in general terms due to the operation of various types of aircraft in a tactical air force and the diversity of tasks carried out by the TAFB. In addition, the aforementioned generality of the TAOS model opens up the possibility of its implementation in the tactical air force in various different countries.

2. BASIC DATA ON AIRCRAFT OPERATING IN THE TACTICAL AIR FORCE

In a tactical air force, military combat aircraft [4] are used, i.e., aircraft [10] of the tactical air force, e.g., multirole fighters, fighters or fighter-bombers. The aircraft operating takes place during the AM execution and as part of the aircraft operating cycle (cycle of aircraft operational usage), which constitutes one of the main parts of an AAAC.

The aircraft operating in the TAOS is defined as an individualized relationship between the airman and the aircraft, which consists of aircraft operation by the airman as an operator (user), for the purposes of executing an AM. As a stage in an AM, the airman makes a flight [15], whose most important phase is to perform the air task (AT) or several ATs. Performing an AT is the main goal of the TAOS. ATs are performed by airmen during AMs that constitute an essential part of a single AAAC. The airmen who take part in aviation work shifts carry out single AAACs, which make up the series of AAACs (SAAAC).

In the following considerations, the authors refer to the "aircraft crew", while using the term "airman", because, in the main, tactical aircraft crew composition and the essential meaning of the term "crew" involve one person. This state of affairs is also connected with the specificity of the tactical air force, because, in most cases (AMs), only a one-person crew (in some cases, there may be a double-person aircraft crew, albeit rarely) operates an aircraft.

The TAOS is a part of the TAFS metamodel. The authors, due to the character of the following considerations, qualify the TAFS as a metamodel, because its individual parts (systems, technical objects, components) at each of its levels can be also outlined as a model in itself. An example of such a description (in terms of the shape of a model) is the TAOS model presented below.

Level 3 of the TAFS metamodel (Figure 1) concerns systems for tactical aircraft operations. This level of TAFS decomposition presents a general and model scheme for tactical aircraft operations on the basis of complex analyses of aircraft's operational state of affairs in the TAFB. Tactical aircraft operations follow a complex operation process [13,14] in a predefined operation system [13,14], which mainly consists of two phases [13,14]: operating (usage) and maintenance. According to the analysed literature [2], there is also a third phase: standby. This means that an aircraft has readiness for duty or immediate deployment, but it is still in the care of military aerospace engineering staff (AES) [5], who are responsible for maintenance. As such, the standby phase is included by the authors in the maintenance phase. Both aircraft operation phases have been comprehensively and extensively described in [13,14].

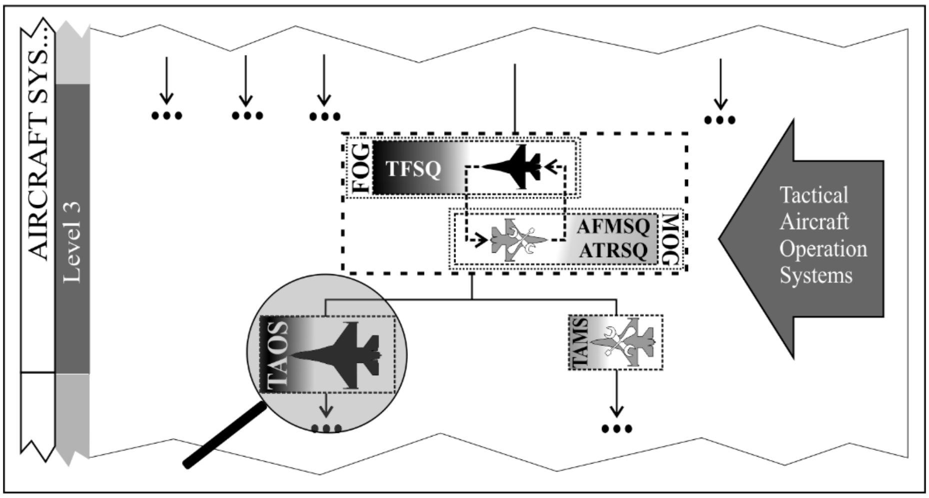

Fig. 1. Level 3 of the TAFS metamodel indicating the research area of this paper (used abbreviations are explained in the text of this paper)

Aircraft operations in the TAFB directly involve the Tactical Flying Squadrons (TFSQs) (Figures 1-2), which operate as a structural part of the Flying Operations Group (FOG) (see Figures 1-2). Military flying staff [4] (airmen) from the FOG/TFSQs with airworthy aircraft or airworthy aircraft with restrictions (aircraft reliability states; see Figure 2) constitute the main elements of the TAOS. The Tactical Aircraft Maintenance System (TAMS) (se Figures 1-2) mainly consists of non-airworthy aircraft or aircraft that are airworthy with restrictions, as well as military AES divided into maintenance squadrons. The maintenance squadrons - the Aircraft Flightline Maintenance Squadrons (AFMSQs) (see Figures 1-2) and the Aircraft Technical Repair Squadrons (ATRSQs) (see Figures 1-2) - operate as a part of the Maintenance Operations Group (MOG) (see Figures 1-2). The TAMS and other systems in the TAFS environment are appointed to support the TAOS, which is treated as the main system in the TAFS.

3. MODEL OF THE TACTICAL AIRCRAFT OPERATING SYSTEM IN THE FORMAT OF AN AGGREGATED ANALYSIS DOMAIN

The TAFS, which is presented in the shape of a metamodel with five levels of decomposition, outlines a new vision, among others, for issues related to the overall state of affairs in tactical aircraft operations. As such, in this article, the TAOS has already been presented among the structures of systems for tactical aircraft operations. Next, using this presentation, the TAOS will be outlined via the format of an aggregated analysis domain. The number of objects, components, processes or operations and events related to the TAOS is significant and, for various scientific analyses, it is necessary to organize them into a coherent and full set of disjointed and individual analysis domains. In the case of outlining the TAOS in the format of an aggregated analysis domain, seven analysis domains (Table 1) were highlighted and emphasized. Within all analysis domains, certain processes take place (Figure 2), integrating their subsequent operations and events, which are described further in both textual and tabular form. Each of the analysis domains is characterized by its multiform interaction with the TAOS environment (domain-environment interaction line; Figure 2). Basically, only five (which are included into the AM; see Table 1, Figure 2) of the seven analysis domains are closely related to the essential (primary) aircraft operations (aircraft operating cycle; Table 1). The remaining two analysis domains are associated with AM preparations and summaries. They are added to the model due to the intention to provide a full picture of issues related to aircraft operating in a tactical air force. In the analysis domains related to AM preparations and summaries, different kinds of domain buffering zones (Figure 2) have been implemented, where the elements of the airman-aircraft anthropotechnical pair are connected or separated and included or excluded to/from the essential operations of the aircraft during the AM (input and output of the airman-aircraft anthropotechnical pair; Figure 2). Furthermore, there are numerous lines that present the circulation of various types of information, information feedback, airman presence (airman line; Figure 2), aircraft presence (aircraft line; Figure 2) with their various reliability states, the airman-aircraft anthropotechnical pair (the line of the airman-aircraft anthropotechnical pair; Figure 2) and possible time breaks. In addition, names of airspace elements have been indicated, which are related to the main part of the TAOS environment. The above-mentioned elements altogether constitute the model of the anthropotechnical TAOS.

Table 1

The general tabular notation of the TAOS in the format of an aggregated analysis domain

AGGREGATED ANALYSIS DOMAIN	**TAOF**						
	ANALYSIS DOMAINS						
	DOMAIN I (PRE-)AM PREPARATIONS	**DOMAIN II** BEFORE TAKE-OFF	**DOMAIN III** DEPARTURE	**DOMAIN IV** AIR TASK	**DOMAIN V** ARRIVAL	**DOMAIN VI** AFTER LANDING	**DOMAIN VII** (POST-)AM SUMMARIES
		AIR MISSION					
		AIRCRAFT OPERATING CYCLE					

3.1. (Pre-)air mission preparations

Domain I (Figure 2, Table 2) constitutes the area of interest that concerns the (pre-)AM (mission) preparations, which are always initiated by the event of a general airman's introduction to the planned AM(s) (Table 2). The aircraft's participation in the processes and their operations and events is not significant. This is mainly limited to the ground training operations and the operation of a pre-flight aircraft exterior inspection before the aircraft is taken over by an airman prior to the commencement of the AM. However, the implementation of processes and operations in Domain I determines the airman's start of the aircraft operating cycle.

The (pre-)AM preparations in the TAOS first involve the main AAAC parts, which take place within the two following processes (Figure 2): Process 1) initial AM preparation (planning) (Figure 2); Process 2) direct AM preparation (informing and updating) (Figure 2). Both processes are described in detail in [3]; therefore, the authors outline below the analyses of Domain I only in tabular form (Table 2). Table 2 presents, in a general and coherent way, the most important processes, operations and events that take place in Domain I.

Table 2

Domain I: Pre-AM preparations

ANALYSIS DOMAIN	PROCESSES OF ANALYSIS DOMAIN		OPERATIONS AND PROCESS **EVENTS** IN THE ANALYSES DOMAIN
DOMAIN I (PRE-)AM PREPARATIONS (AMS)	1	**Initial AM preparation (planning)**	**General airman's introduction to planned AM**
			Detailed analysis of documentation, orders, specialist publications etc. in the scope of the planned AMs
			Familiarization with safety systems and emergency procedures
			Developing of an AM scenario
			Preparation of mission data cards necessary for AM execution
			Ground trainings
	2	**Direct AM preparation (informing and updating)**	Mass briefing
			Briefing
			Step briefing
			Life support equipment inspection and its takeover by airman
			Pre-flight aircraft exterior inspection (walkaround checklist) and **aircraft takeover by airman** - aircraft transfer from the TAMS to the TAOS

3.2. Before take-off

Domain II (Figure 2) of the TAOS concerns the processes and their operations as carried out by the airman after the aircraft is physically and formally transferred from the TAMS to the TAOS (aircraft line; Figure 2) at the time of the aircraft's takeover by the airman (when the airman signs the aircraft service card [5]). After the last event in Domain I, there begins a series of processes and their operations in Domain II, which is directly connected with the airman-aircraft relationship. It is assumed that the airman-aircraft anthropotechnical pair is activated then. It should be noted that the aircraft, which is transferred from the TAMS to the TAOS, is characterized by a certain reliability state (level of airworthiness; Figure 2), with the required amount of fuel (variant of refuelling), the variant of weaponry, and various different parameters and variables also determining the type of the WM and the type of the AT in which it can be used. The aircraft transferred to the TAOS may be in one of the following reliability states (Figure 2): airworthy (without restrictions) or airworthy with restrictions [6]. The above-mentioned variables are always well defined by the airman during the processes and operations in Domain I and transferred in order to be implemented by the AES (aircraft set-up information line; Figure 2).

The following two main processes (Figure 2) take place in Domain II: start-up of the power unit and systems, along with their checks (Process 1; Figure 2) and pre-take-off taxiing (Process 2; Figure 2). During the two processes, many different operations are performed by the airman. After the operation of the radio check, the airman (proceeding according to the appropriate checklists) conducts the following operations: start-up of the power unit and on-board systems (avionics, hydraulics etc.), checking and configuring the power unit and on-board systems, receiving ATC (air traffic control) clearance [6] (which permits the airman to taxi before take-off and could contain departure instructions), first phase of taxiing (the last opportunity [5] where the aircraft is checked prior to take-off by the special control group from the AES), the last-possible check of the aircraft, second phase of taxiing (to the runway holding position [10]).

3.3. Departure

Domain III (Figure 2), in a general way, presents the transition of the anthropotechnical pair between the two stages of the AM: from pre-flight ground operations to the flight. It is assumed that the “departure” is of a symbolic nature in Domain III, which is associated with the main operation in the process of leaving, i.e., the operation of executing the departure from the (Military) Air Traffic Zone ((M)ATZ) or the (Military) Control Zone ((M)CTR)/(Military) Terminal Control Area ((M)TMA) (Process 3; Figure 2) [6]. However, before conducting this main operation, the process involving line-up checks and pre-take-off [15] preparation (Process 1; Figure 2) must takes place including with the following operations: lining up on the runway in use (line-up checklist) and accomplishing the pre-take-off checklist items. After these operations, the process of take-off (Process 2; Figure 2) begins. There are two take-off options: static or rolling [18]. The main operations in the process of take-off are: receiving take-off ATC clearance, take-off rolling with the event of the take-off (aircraft detachment from the runway surface) and initial climbing [15], which is determined at the height of 15 m above ground level. At the time of the event of the aircraft take-off from the runway surface, the flight as a stage of the AM begins. The main objective of the take-off process is to safely get the aircraft airborne.

When initial climbing is completed and the aircraft is configured to fly (when the gears and flaps are retracted and lights are switched off, the aircraft is airborne), the airman conducts the operation of departure from the (M)ATZ or (M)CTR/(M)TMA. This operation is conducted according to the departure instructions that were given by an ATC officer (ATCO) [6] during ATC clearance (Domain II and Process 2). If the departure instructions are published as a Standard Instrument Departure (SID) [11], then the ATCO only gives the airman the name of the SID. On the other hand, they might directly result from the current traffic situation in the (M)ATZ or (M)CTR/(M)TMA, in which case the ATCO gives complete departure instructions by radio. It is important for the airman to accurately follow the received departure instructions in order to avoid air collisions with other aircraft or terrain obstacles, and without violating the horizontal and vertical boundaries of the airspace. Process 3 within Domain III ends with the event of reaching a significant point [11] in the (M)ATZ or (M)CTR/(M)TMA during the departure. The ATCO in a given ATC clearance (in the part that refers to the departure instructions) specifies this significant point towards which the operation of leaving the (M)ATZ or (M)CTR/(M)TMA should be conducted or this point is defined in a published SID.

3.4. Air task

Domain IV (Figure 2) is the essential part of the TAOS and even constitutes a kind of core or purpose, which determines the legitimacy of establishing this system. The AT is the main phase of the flight and constitutes a set of specific and target actions on the part of the airman/airmen during the flight within a set time and area, which are performed to achieve the AM’s desired objectives such as: training, operational or combat objectives. It is determined by the superior, instructor or formation leader [17,18] and performed by the airman as an operator who operationally uses the aircraft in the TAOS. There are many different types of ATs, and it is impossible to describe all of them. Each type of aircraft or its equipment is predisposed to perform particular ATs. However, there are processes, including operations and events, which usually take place within the ATs performed during the AM.

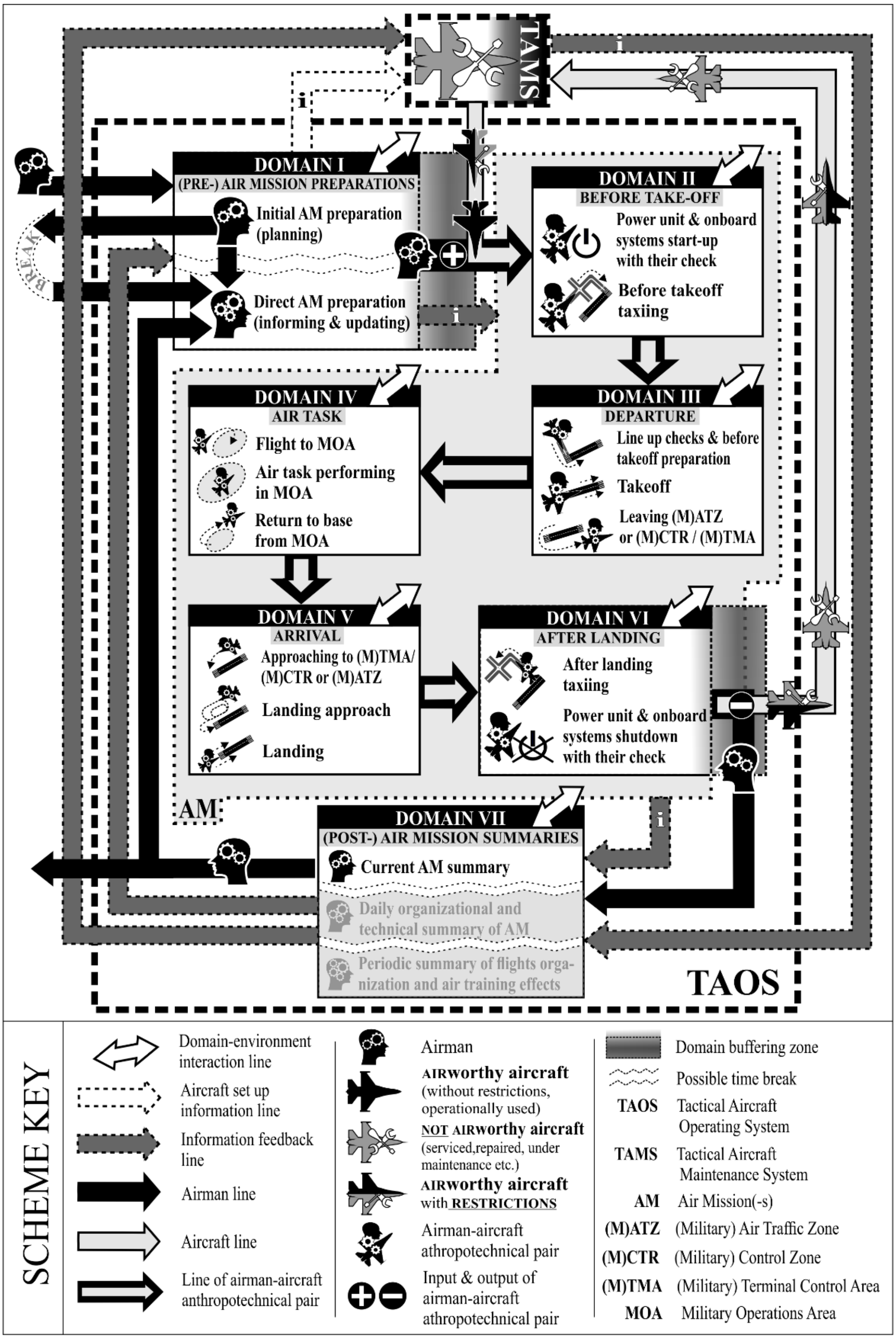

Fig. 2. Model of the TAOS in the format of the aggregated analysis domain

The first process (Process 1; Figure 2) in Domain IV is known as the flight to the MOA [19] and includes the following operations: en route navigation flight towards the MOA (after the event of reaching the significant point in the (M)ATZ or (M)CTR/(M)TMA), reporting on intentions that concern the planned AT performance, and the FENCE check-in [17,18] (the in-flight check before the aircraft enters the MOA, which involves checking and configuring the particular on-board systems before the beginning of the AT performance). Due to the different types of ATs and other variables, the airman can accomplish various additional in-flight checks, which are also indicated by appropriate acronyms (e.g., OPS check, BD check [17,18]).

The second process (Process 2; Figure 2) concerns the AT performed in the MOA, i.e., achieving the desired AM objective. ATs may take many different forms, but usually the process of performing an AT in the MOA includes the following operations: entering the MOA (other airspace), recognition of the tactical air situation, performing the AT. The event of the completion of the AT closes Process 2 in Domain IV.

The last process in Domain IV (Process 3; Figure 2) is known as the return to base (RTB) from the MOA and takes place after the completion of the AT. This process begins simultaneously with the operation of the FENCE checkout [17,18], i.e., the in-flight check before the aircraft is exiting the MOA, which involves checking and configuring the particular on-board systems after the completion of the AT. Next or even at the same time, the airman reports from the air about the completion of the AT and declares the readiness to RTB. The last operation in Process 3 concerns the flight towards a base aerodrome or an alternate aerodrome [4,10] in the case of poor meteorological conditions or due to other circumstances (variables), which preclude a landing on the base aerodrome.

This above description of Domain IV should be treated as general, because each type of air task requires an individual approach.

3.5. Arrival

Domain V (Figure 2) concerns the processes and related operations that take place during the final phases of the flight. These processes and operations require the airman’s special concentration and full situational awareness. The main processes in Domain V are: approaching [11] the (M)TMA/(M)CTR or (M)ATZ (Process 1; Figure 2), landing approach [11] (Process 2; Figure 2) and landing [15] (Process 3; Figure 2).

The process of approaching the (M)TMA/(M)CTR or (M)ATZ includes the operation of initial descending and entering the (M)TMA/(M)CTR or (M)ATZ, the event of reaching the significant point in the (M)TMA/(M)CTR or (M)ATZ during the approach and also the operation of the further descent in the (M)TMA/(M)CTR or (M)ATZ.

The landing approach process includes three main operations, which are named by the authors in a very general way. This is due to the fact that this process can proceed according to different rules of flight (visual flight rules/instrument flight rules [11]), procedures (visual approach/instrument approach [11]) or flights manoeuvres (standard pattern, closed pattern etc. [9]), which depend on many different variables and parameters. Process 2 includes the operation of executing the landing approach, i.e., the aircraft air manoeuvre in the (M)TMA/(M)CTR or (M)ATZ, according to the published pattern (approach chart), or with radar vectoring provided by ATC (e.g., precision approach radar [6]). Next, there is the event of positive visual contact with the runway (runway in sight) or negative visual contact with the runway, which reinforces the necessity of executing the missed approach procedure. The final event involves making the decision to continue the landing approach operation (Process 3 will begin) or abort the landing approach operation (Process 3 will be postponed).

3.6. After landing

Domain VI (Figure 2) includes two processes that contain the third AM stage operations. The process of post-landing taxiing (Process 1; Figure 2) includes the following operations: vacating the runway, configuring the aircraft for taxiing (post-landing checklist: retracting the flaps, switching off the lights etc.), and aircraft taxiing to the hangar, apron or aircraft stand [12]. When the aircraft stops on the apron, stands or comes to a halt in the hangar, the process of power unit and on-board system shutdown, along with the respective checks (Process 2; Figure 2), takes place. In this process, the airman firstly operationalizes the power unit and on-board system shutdown, which accomplishes the shutdown checklist. Next, the power unit and on-board systems are checked and configured by the airman at the time of standing, thus accomplishing the pre-exit aircraft checklist. The event of the airman's exit from the aircraft cockpit completes the third (and last) stage of the AM.

3.7. (Post-)air mission summaries

Domain VII (Figure 2, Table 3) concerns the (post-)AM summaries, one or several that are executed at a particular time. AM summaries include: current AM summary (Process 1; Figure 2) conducted after every finished AM within a single AAAC, daily organizational and technical summary of AMs (Process 2; Figure 2) conducted at the end of an SAAAC and closing the aviation work shift, periodic summary of flight organizations and air training effects (Process 3; Figure 2) conducted after several completed SAAACs in a particular period of time, but not less than once a month.

Table 3

Domain VII: (Post-)AM summaries

ANALYSES DOMAIN	PROCESSES OF ANALYSES DOMAIN		OPERATIONS AND PROCESS **EVENTS** IN THE ANALYSIS DOMAIN
DOMAIN VII (POST-)AM SUMMARIES (AMS)	1	**Current AM summary**	Informing the maintenance staff about details that concerns aircraft technical issues, which appeared during the flight
			Analysing the flight data recorders
			Debriefing
			Debriefing end - formulating conclusions and recommendations that result from the performed AM (end of a single AAAC)
	2	Daily organizational and technical summary of AMs	Conducting the assessment of: the work quality of flight organization services, the level of aircraft airworthiness, the flight support measures, the AM training effects, etc.
			Formulating conclusions and recommendations that concern entire aviation activities during the given aviation work shift (during one series of AAACs)
			Aviation work shift end (end of a given SAAACs)
	3	Periodic summary of flights organization and air training effects	Conducting analyses of a flight organization and air training effects in an TAFB in a given period of time
			Formulating conclusions and recommendations that concern entire aviation activities during a given period of time (after several SAAACs)
			Summary note preparation

Processes 2 and 3 are marked in grey (Figure 2, Table 3) due to the fact that they are not conducted only after a single AM/single AAAC. All three types of summaries are described in detail in [3].

4. CONCLUSIONS

The above-presented concept of the TAOS, in an innovative way, outlines one of the inner systems from the TAFS. The adopted format of the model, in a general and coherent way, presents processes including their operations and events, which are related to aircraft operations (aircraft operational usage) in the tactical air force. This concept of the model clearly explains the basic issues related to tactical aircraft operations. Furthermore, the format of the TAOS model presented in this paper can be successfully implemented in other types of military aviation. It could also be used to outline other system objects or components found in the metamodel of the TAFS, e.g., the TAMS.

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