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OBJECTIFICATION OF SUBJECTIVE ESTIMATION OF ABNORMAL CASES DANGER IN AIR TRAFFIC CONTROL

Summary. In the article, the problems of objectification of the subjective danger estimation for abnormal cases in air traffic control are considered. An overview of currently existing approaches is given. In addition, the article presents the analysis of the statistical results of testing 252 air traffic controllers. This study reveals a subjective danger estimation inadequacy and its connection to air traffic controller's potential extreme working capacity. A new approach to objectification of the subjunctive danger estimation for abnormal cases in air traffic control is proposed. The method combines the conditional probability collision computation and the method of expert estimations.

1. INTRODUCTION

Air traffic control (ATC) is the most important component of aviation transport system when it comes to safety. This component is constantly improving and developing [1]. Nevertheless, every year a number of dangerous incidents due to ATC errors happen all over the world. As an example, in August 2, 2016, there was an occurrence of near collision of two aircrafts belonging to IndiGo airline. At that moment, the aircraft diverted at such little distance that due to a shock four passengers and two flight attendants had to seek medical care. Only in this year, 17 similar situations have been registered in India, in the past year, 25 near collisions occurred, and there were 31 cases in the year 2014 [2].

In Russia, in 2015, 24 incidents happened regarding violations in separation (in 2014, there occurred 35 incidents because of the same reasons) [3]. Fig. 1 shows the distribution of incidents according to the factors leading to violation in separation throughout the year 2015.

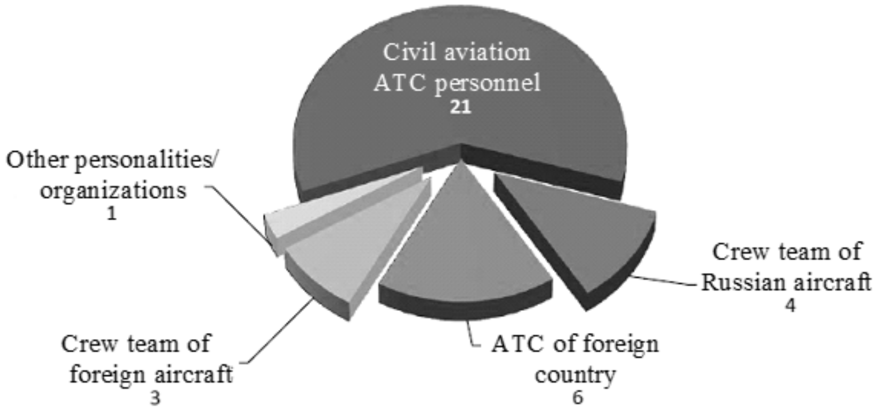

Fig. 1. Distribution of the factors of incidents related to violations in separation that occurred in 2015 [3]

As one can see from the given diagram in Fig. 1, among the factors of the incidents related to violations in separation, a greater portion of the reasons refer to ATC personnel (including ones related to the wrong ATC's danger assessment of the potentially occurring traffic conflicts). Therefore, the problem of danger objectification for abnormal cases while ATC considered in this article seems important and of great current interest.

2. PRIOR STUDIES AND REFERENCES ON THE PROBLEM OF OBJECTIFICATION OF ABNORMAL CASES IN ATC

The adequacy of the danger assessment for the abnormal cases (ACs) by a pilot or an air traffic controller, as it was shown in [4, 5], is an important indicator of a human / operator's psychological resistance, allowing one to assess his/her potential working capability in stress situations. At this point, an important question arises: what is an objective danger of AC relatively to one we compare an assessment given by a test person.

If for an AC on board of an aircraft the method of expert assessments is almost the only way to get the objective assessment of the AC danger, then for the ATC, the situation is somewhat different. Most of all the attempts to assess the probability of aircraft collision are made using different models [6-8] both with statistics about near misses and premises to them [1, 3, 9-12] and different theoretical concepts [13-18]. But manuals [7, 8] describe the models which support procedure separation mainly. The corresponding models of lateral and vertical separation do not consider any interference of an ATC. The models of longitudinal separation based on horizontal intervals take into consideration this condition, but they are efficient under a low data update rate only. Besides, minimum of longitudinal separation is sufficient for a successful interference [6]. These uniform principles (the risk modeling for an AC collision) do not consider the aspect of high data update rate for observations in a model of collision risk due to exploitation errors. This aspect is mentioned just to emphasize that the given principles are applied only to the collision risk models in Doc 9689 and Doc 9574, and none of them consider modeling of exploitation errors during radar observation [6]. In fact similar models with the same restrictions are offered in the works [13-18].

In ATC automated systems, one of the main ways to improve aviation safety is the preliminary detection of a conflict situation (CS). Recently developed utilities for informational support of ATCs' operation in the modern ATC automated systems are supplemented with the detection algorithm of conflict situations in airspace. An exact problem solution demands exhaustive search of scenarios on hundreds of objects, and due to impracticability to compute the solution in real time, it is usually not considered. Traditional schemes of exhaustive search reduction are based on heuristic double-stage procedures' information filtration about moving aircraft. They allow one to reduce the enormous exhaustive search on hundreds of objects to a search on the very few of objects [19]. In fact, the papers [19-24] consider different ways for the problem solution without a human factor (HF) influence on ATC. They utilize an ideology similar to one outlined in [6-8, 13-18].

As it has rightly been said [25]: "The main task of flight operations safety management system of a prognostic type consists in providing rational level of risks under control for flight operating safety (FOS) and operational errors. To solve the task, one has to find the danger-producing factors and assess urgency and frequency (probability) of events which can occur as a result of influence of these factors. When assessing flight operations safety together with technical factors as a key aspect, one has to take into consideration the human factor. At present, the main method of recognition of factors mentioned above is the method of "brainstorming" carried out by a group of highly skilled experts including air traffic controllers, pilots, and other specialists. The assessment of risks includes the assessment of the urgency of events connected to identified dangerous factors and the estimation of frequency for these events, namely, the determination of the expected amount of aviation incidents and the incidents of a particular kind per flight hour. To assess the probability of an appearance of the dangerous factor consequences experts use available statistics. Such an approach has a number of disadvantages coming from subjectivism of the expert assessments, probable non-detection (missing) of threatening factors, absence of sufficient statistics used for statistical assessment within a confident interval". In work [25] the assessment of risk is made with the help of a simulated model. In particular "A simulated model considers the following danger factors: ... ATC's mistakes when making a decision. These mistakes are simulated as ATC's actions on detecting eventual conflict situation occurring when aircraft are carrying out a flight plan and the ATC's response to them. The ATC's mistakes include disregard of eventual conflict situation leading to different types of real conflicts (violations in separation intervals, aircraft near collisions, etc.). ATC's delay in making decisions are taken into consideration by creating a queue of actual operations and estimating waiting time of command execution in the ATCs' model. This delay can lead to late ATC's instruction on conflict situation resolution and, thereby, lead to an airspace incident". However, the works [25-26] do not consider this case in detail.

There was also an interesting attempt to take into account HF in ATC [27]. According to this paper, the probability to miss an eventual conflict by an ATC is determined by an ATC's workload and a depth of the situation development (the order of the analysis step), but one does not take the subjective component into consideration as well.

The paper [28] proposes a way of an objective danger assessment for an abnormal case in the period of time τ_j, which an ATC has in order to detect and eliminate the AC, but the whole refusal from the expert danger assessments would be unreasonable. The indicator τ_j does not allow assessing the danger of a specific AC to the full extent.

In work [28] one decomposes the results of the ATC's work, which gives the classification of routine tasks and as well as ACs in ATC. It is quite evident that with the same value of a τ_j we will get the AC of different dangers. Therefore, the quantitative method offered in [28] is not quite satisfactory because of a weakness of assumed speculative initial conditions.

Thus, at present, there are no satisfactory methods for objectification of the AC danger assessment in ATC, and new research in this direction is required.

3. THE PRIOR RESEARCH AND REFERENCES ON THE PROBLEM OF THE ATC's POTENTIAL EXTREME WORKING CAPACITY

The problem of objectification of AC danger is closely connected with the problem of the ATC's potential extreme working capacity (PEWC) assessment.

As early as 1975, N. F. Mikhailik proved that pilot's successful behavior in AC depends first of all not on his qualification, flight hours, etc., but the number of AC in which the pilot had been involved in during the flights. The nerve centers, i.e. the formations of different levels of the central nervous system (CNS), the mutual activity of which provides realization of a particular function of the entire organism, are formed during AC experience and cannot be created by any other way. The constellation of these nerve centers makes the material substratum of the psychological phenomenon called "emotional experience" (EE) [5].

Emotional experience is a collection of expertise, knowledge, and skills on overcoming extreme situations that arise and becoming stable on the background of strong emotional experiences of especial importance and responsible and dangerous actions. This is some stable structure obtained from the synthesis of a great number of activities in the co-occurring extreme situations and emotional-volitional mental status imprinted in the emotional memory (authors' definitions [3]). Precisely this emotional experience prevents a destructive effect from happening owing to a pilot's stressed mental condition that arises during an AC. Such an experience is not a notice on a piece of paper or another inanimate medium. Under the influence of mental workload in the central nervous system, new connections and tension foci appear, i.e. not only the recording of information takes place but also "training" happens. Thus, not only the recording is changed but also the carrier itself. Very important and stable changes in neurochemical and neurophysiological mechanisms are taking place supporting the highest functions of brain, i.e. new behavioral hemostasis and long-term memory engrams form. Under the influence of stress, a burst release of a great number of hormones takes place, and the composition of solids in the synaptic cleft changes. Thereby the character and speed of the inter-neuronal interaction changes abruptly. However, the further growth of psychological tension connected with growth of danger in the process of the AC development can lead to a deformation of the emotional experience. Depending on the state of the CNS, a person under stress can either mobilize his/her opportunities or vice versa go into perplexity up to complete stupor. The return to a normal condition leads to rehabilitation of homeostasis but not to initial one – the traces remain (residual information). For the first time, the notion of emotional experience was introduced by N. F. Mikhailik [29]. He also introduced the notion of its deformation during the AC. Except that it was discovered that this deformation occurs not continuously but discretely, "layer by layer" because (and apparently as a consequence) EE as well as its material substratum represents multilevel hierarchic structures, consisting in this particular case of five strata: cooperation, cognitive, volitional, motorial, and biological experience [5, 29].

Thus, a personal EE can be represented as a multilevel hierarchic structure, consisting of 5 strata every one of which corresponds to one of the aforementioned types. It was also noticed that the destruction sequence of the given strata during the AC is different among different operators. Some operators had the sequential destruction of strata – "one by one" – and others had "a leap", i.e. the destruction of several strata has been occurred pretty much simultaneously. What kind of a theory can describe and so foresee the occurrence of such a process in the operator's psyche? N. F. Mikhailik proved that for the description of the given process, "Theory of Accidents" by Rene Thom can be used [5, 30, 31].

In a real situation, transitions from one level of danger exposition experience to another level often take place without irreversible consequences. Therefore, in the description of one abnormal situation one can see availability of a few levels consequently appearing in the course of development of the abnormal cases. The process of the deformation of the experiment is followed by energetic cost increasing with the decreasing level of the experiment – from the experiment of cooperation to biological experience. Then one can assess the deformation of emotional experience on the scale proposed earlier in [29].

As a variable *S,* a level of a human-operator's emotion experience deformation under stress factors of an abnormal case (AC) is taken. The variable *S* is estimated in figures from zero (when there is the complete absence of the emotional experience) up to five. The scaling of the state variable was held on the bases of an expert interview of a few thousand of the participants [29].

To determine how psychologically stable a human operator will be in an extreme situation, the term of potential extreme working capability is used [4, 5]. For a pilot, the method of its estimation is based on the usage of the scale *S* and is well-documented in the work [5]. As the methods had a number of serious disadvantages, in particular, the necessity to hold the estimation of working capability only in the process of training in the program "CRM of Russia" [5] and high professional requirements by an instructor, since the adequacy of the estimations of the EE deformation (*S*) of the AC participant depends considerably on instructor's experience and his/her professional "scent", A.V. Malishevskii proposed a novel methodology [4]. However, as it has been seen from the data given in [32, 33], the methodology is not perfect enough. It follows from the results [33] of mass survey of ATCs held by A.V. Malishevskii; the relatively small and not very significant differences in estimations of the AC danger led to a considerable spread of extreme working capability estimations determined by the methodology [4]. Therefore, the authors [5] offered a new improved methodology for determination of operator's EWC, which is already well operated on ATCs.

ATC's EWC is the predicted ATC's working capability for the performance of the right and timely acts during some potentially enabling abnormal case arising in operational ATC while in aircraft flight mode or some danger during aircraft ground movements, factors or their combination which lead to reduction of aviation safety [5].

The observations made previously by N.F. Mikhailik, A.V. Malishevskii, and R.M. Dzhafarzade [4, 5, 32] were used as a basis of the methodology [5]. According to their observations, inborn component of EWC is predetermined first of all by emotional stability of a human-operator, i.e. neuroticism (*n*). According to the authors, the component acquired during professional activity of a pilot is adequately characterized by a capability for danger assessment of an abnormal case by this operator. All the methodologies of EWC assessment referenced earlier differed in general by the assessment methods for the acquired component of EWC.

The subjective AC danger estimation (φ_S) is the estimation of AC danger on a special scale (Fig. 2) by its direct participants [5, 32].

The objective estimation of AC danger (φ_O) is the generalized group estimation of an abnormal case danger on a special scale obtained by the processing of individual expert estimations [5, 32].

Conditionally objective estimation of danger (φ_{YO}) is an objectified estimation of AC danger by its participant on a special scale obtained by correcting of its subjective estimation by a special procedure [5, 32].

Denoting φ_{Si} and φ_{Oi} the subjective and objective danger estimations for the i-th AC, respectively, and recovering the values $\{\varphi_{Oi}, \varphi_{Si}\}_{i=1}^{N}$ for the set of N ACs from a databank, one formulates the dependence as follows:

$$\varphi_{YO} = a\varphi_S + b, \tag{1}$$

where N is the number of estimated AC;

$$a = \frac{N\sum_{i=1}^{N}(\varphi_{Oi}\varphi_{Si}) - \sum_{i=1}^{N}\varphi_{Oi}\sum_{i=1}^{N}\varphi_{Si}}{N\sum_{i=1}^{N}\varphi_{Si}^2 - \left(\sum_{i=1}^{N}\varphi_{Si}\right)^2};$$

$$b = \frac{\sum_{i=1}^{N}(\varphi_{Oi})\sum_{i=1}^{N}\varphi_{Si}^2 - \sum_{i=1}^{N}\varphi_{Oi}\sum_{i=1}^{N}(\varphi_{Si}\varphi_{Oi})}{N\sum_{i=1}^{N}\varphi_{Si}^2 - \left(\sum_{i=1}^{N}\varphi_{Si}\right)^2}.$$

This dependence, as a rule, differs from the ideal dependence of form

$$\varphi_{YO} = \varphi_S. \tag{2}$$

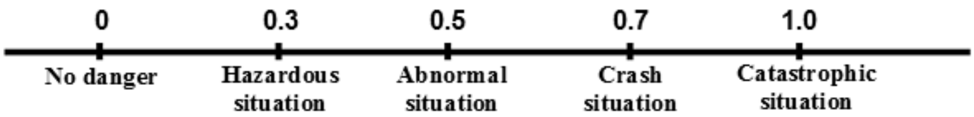

Fig. 2. The scale of the AC danger estimation (the classification of AC)

The variations of estimations $\varphi_S \pm 0.1$ from φ_O are acceptable as according to the special scale [4, 5]; given in Fig. 2, the step Δ_φ between different categories of the AC is of 0.2. The precision of half scale division is quite admissible. In this case it seems quite acceptable to ignore little deviations from the absolute adequate estimation denoted by the expression (2) restricted by functions

$$\varphi_{YO} = \varphi_S - 0.1; \tag{3}$$

$$\varphi_{YO} = \varphi_S + 0.1. \tag{4}$$

To determine the adequacy of the estimation of the AC danger the following value is used:

$$\sigma_\Sigma = K\sigma_A + \sigma_B, \tag{5}$$

where σ_A is the area proportional to the degree of the AC danger overvaluation (it corresponds to the filled area in Fig. 3); σ_B is the area proportional to the degree of the AC danger undervaluation (it corresponds to the filled area in Fig. 3); K is a multiplying coefficient as according to the opinion given in [5]; overestimation of danger in an AC from the point of view of EE deformation is much more dangerous than its underestimation (Authors [32] in this case emphasize that the overestimation of danger in an AC is more dangerous from the point of view of the EE deformation but not due to probable consequences which can occur also because of the late decisions making to overcome the current situation).

Next according to the diagram one can easily determine the value m as the function of σ_Σ, and EWC is determined as the sum of n and m [5, 32].

The most difficult moment is to determine φ_O because it was shown earlier there are no quite satisfied methods of objectification of the AC danger estimation in ATC presently. In [32-34] φ_O is derived as an averaged value from subjective danger estimations of all or part of the experiment participants, i.e. by a quite primitive expert survey, and this produces some doubts in the received results.

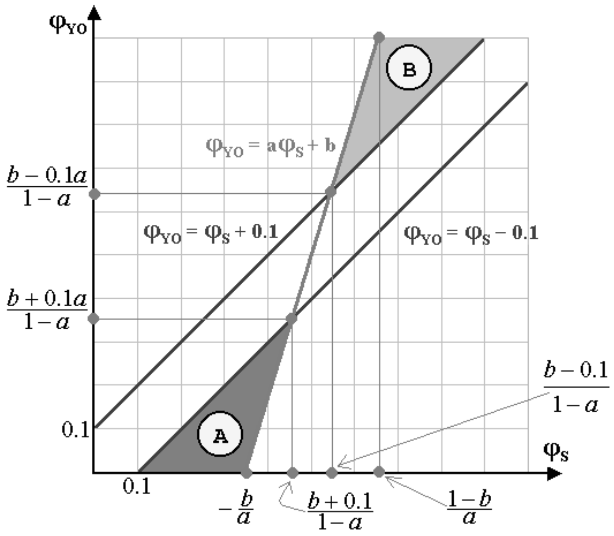

Fig. 3. The graphical interpretation of determining the AC danger estimation adequacy [5, 32]

4. SOME RESULTS OF THE ATCs DANGER ESTIMATION OF ABNORMAL CASES

Regardless of the challenges with objectification, results in [5, 32-34] definitively highlighted some interesting moments. Considering the results (Table 1) [5] air traffic controller #6 estimated the same case more dangerous than all the other controllers. It is quite clear that the average estimation will be a highly inaccurate equivalent for the AC objective danger estimation (φ_O). Thus, a problem of inadequacy of the ATC danger estimation exists. Although the inaccurate results for ATC danger estimations can occur [5], the inverted result, clearly, does not correspond to real value φ_O.

Such inverted results are not encountered so rarely. In University of Civil Aviation the data about 252 air traffic controllers from different ATC centers were collected and the wrong results were discovered in 10% of the cases. This proves the importance of the problem for the AC danger estimation objectification. One of the ways to increase the accuracy for this estimation is the usage of special methods of expert survey or at least the better selection of the experts of skilled level, although the subjectivism of estimations cannot be avoided.

Table 1

The results of the subjective and "objective" AC danger estimation from [5]

ATC	1	2	3	4	5	6	7	8	9	10	11	12	Average
φ_{S1}	0.3	0.5	0.5	0.3	0.3	0.35	0.45	0.35	0.55	0.45	0.5	0.6	0.429
φ_{S2}	0.1	0.15	0.3	0.3	0.3	0.5	0.15	0.1	0.25	0.25	0.3	0.15	0.238

A.V. Malishevskii and R.A. Mamedov [33] carried out an experiment on the participants in the refresher courses (RC) who were given two ACs (the same as in [5]). The participants were offered to give estimation of AC danger and elaborate operational procedures to prevent an aircraft collision. As experts from ten respondents, only eight were selected whose qualification and greater experience did not raise doubt, and the fifth and the sixth participants were registered hereinafter as "other participants of the experiment". The data are shown in Table 2.

Table 2

The subjective estimations of AC danger [33]

ATC	φ_{S1}	φ_{S2}	ATC	φ_{S1}	φ_{S2}	ATC	φ_{S1}	φ_{S2}
1	0.5	0.1	24	0.5	0.3	47	0.5	0.3
2	0.3	0	25	0.3	0.3	48	0.7	0.5
3	0.5	0.3	26	0.3	0	49	0.5	0.3
4	0.5	0	27	0.5	0.3	50	0.5	0.3
5	0.3	0	28	0.3	0	51	0.4	0.2
6	0.5	0.3	29	0.5	0.3	52	0.5	0.175
7	0.3	0	30	0.5	0.3	53	0.45	0.15
8	0.5	0	31	0.5	0.3	54	0.35	0.1
9	0.3	0.1	32	0.3	0	55	0.4	0.175
10	0.5	0.15	33	0.3	0	56	0.45	0.175
11	0.5	0.3	34	0.5	0	57	0.4	0.15
12	0.3	0.3	35	0.5	0.3	58	0.45	0.15
13	0.3	0.3	36	0.3	0	59	0.3	0.125
14	0.35	0.5	37	0.3	0.3	60	0.4	0.15
15	0.45	0.15	38	0.5	0.5	61	0.4	0.15
16	0.35	0.1	39	0.5	0.3	62	0.45	0.15
17	0.55	0.25	40	0.3	0	63	0.5	0.2
18	0.45	0.25	41	0.5	0.3	64	0.4	0.15
19	0.5	0.3	42	0.5	0.3	65	0.45	0.1
20	0.6	0.15	43	0.5	0.3	66	0.5	0
21	0.5	0.3	44	0.5	0.3	67	0.5	0.3
22	0.3	0	45	0.3	0.3			
23	0.3	0.3	46	0.5	0.3			

As φ_O the average value φ_S over 8 experts, 59 ATCs (the participants of the experiment), and 67 participants in total was computed. The resulting values of φ_O in every case are presented in Table 3.

As expected the difference in the results appeared to be significant. The experts' values of φ_S varied from 0.5 to 0.3 on the first scale of the AC and from 0.3 to 0 on the second one. All of the participants estimated the first case as more dangerous. Spreading of estimations for the other participants is considerably larger: from 0.7 to 0.3 on the first scale and from 0.5 to 0 on the second scale, with that 8 participants (11.9%) considered the danger of the first case to be equal to or even exceeding the danger of the second AC. Influence of these data impaired the final result.

Table 3

The objective estimations of AC danger [33]

Average	Total	φ_{O1}	φ_{O2}
Experts	8	0.425	0.088
Participants	59	0.431	0.211
All participants	67	0.431	0.196

Following the results of this experiment one can apparently confirm that there is the problem of the AC danger adequate estimation in ATC as at least 12% of respondents have other opinion on the AC danger in comparison with the rest (88% of the respondents). Despite of some drawbacks, the method of expert estimations for objectification of the AC danger estimation is applicable.

The same results were shown by the experiment held under the supervision of A.V. Malishevskii, V.E. Degoltseva, and M.A. Podterebova [34] which included 9 students and 22 ATCs from Rostov and Krasnoyarsk ATC centers. In this experiment, a near miss was used which happened in the area of responsibility of Saint-Petersburg ATC center. As a result, two aircrafts descended at the distance of 6 km at in-trail descent. Two aircraft entered the area of the area control center at the same time following the same route at FL 320 and FL 340 respectively. The lower aircraft had an instruction to descend to FL 140 and the upper one to FL 160. There were no instructions on the rate of climb. At this time, the upper aircraft had a greater vertical speed than the lower one and it overtook the lower aircraft as it is shown in Fig. 4. A total 5 fragments of this AC were used (the fourth is shown in Fig. 4). All the participants of the experiment showed the high level of EWC. However, with that, it turned out that the students evaluate this case as much less dangerous than the professional ATCs (Table 4). This suggests that it is necessary to improve the professional education of students.

Table 4

The initial data for the EWC estimation of the experiment participants [34]

Participant of the experiment	Fragments				
	1	2	3	4	5
Students					
1	0	0	0.2	0.4	0.5
2	0	0.3	0.4	0.5	0.7
3	0	0.3	0.3	0.5	0.5
4	0	0.1	0.3	0.6	0.7
5	0	0.3	0.3	0.5	0.5
6	0	0	0.2	0.5	0.8
7	0	0.2	0.4	0.5	0.5
8	0	0	0.3	0.4	0.5
9	0	0.2	0.3	0.4	0.5
Air traffic controllers					
1	0	0.3	0.5	0.7	0.8
2	0	0.4	0.4	0.6	0.9
3	0	0.3	0.4	0.6	0.8
4	0	0.3	0.3	0.7	0.7
5	0	0.3	0.3	0.5	0.8
6	0	0.3	0.3	0.7	1
7	0	0.2	0.5	0.7	0.9
8	0	0	0.3	0.5	0.5
9	0	0	0.5	0.8	0.8
10	0	0.5	0.5	0.8	1
11	0	0.3	0.5	0.7	0.7
12	0	0.3	0.5	0.7	0.7
13	0	0.3	0.3	0.7	0.7
14	0	0	0	0.7	1
15	0	0.5	0.3	0.7	0.7
16	0	0.3	0.3	0.7	1
17	0	0.5	0.5	0.7	0.7
18	0	0.2	0.3	0.7	0.7
19	0	0.2	0.2	0.9	0.8
20	0	0.3	0.3	0.5	0.3
21	0	0.3	0.5	0.7	0.7
22	0	0	0.3	0.7	0.7

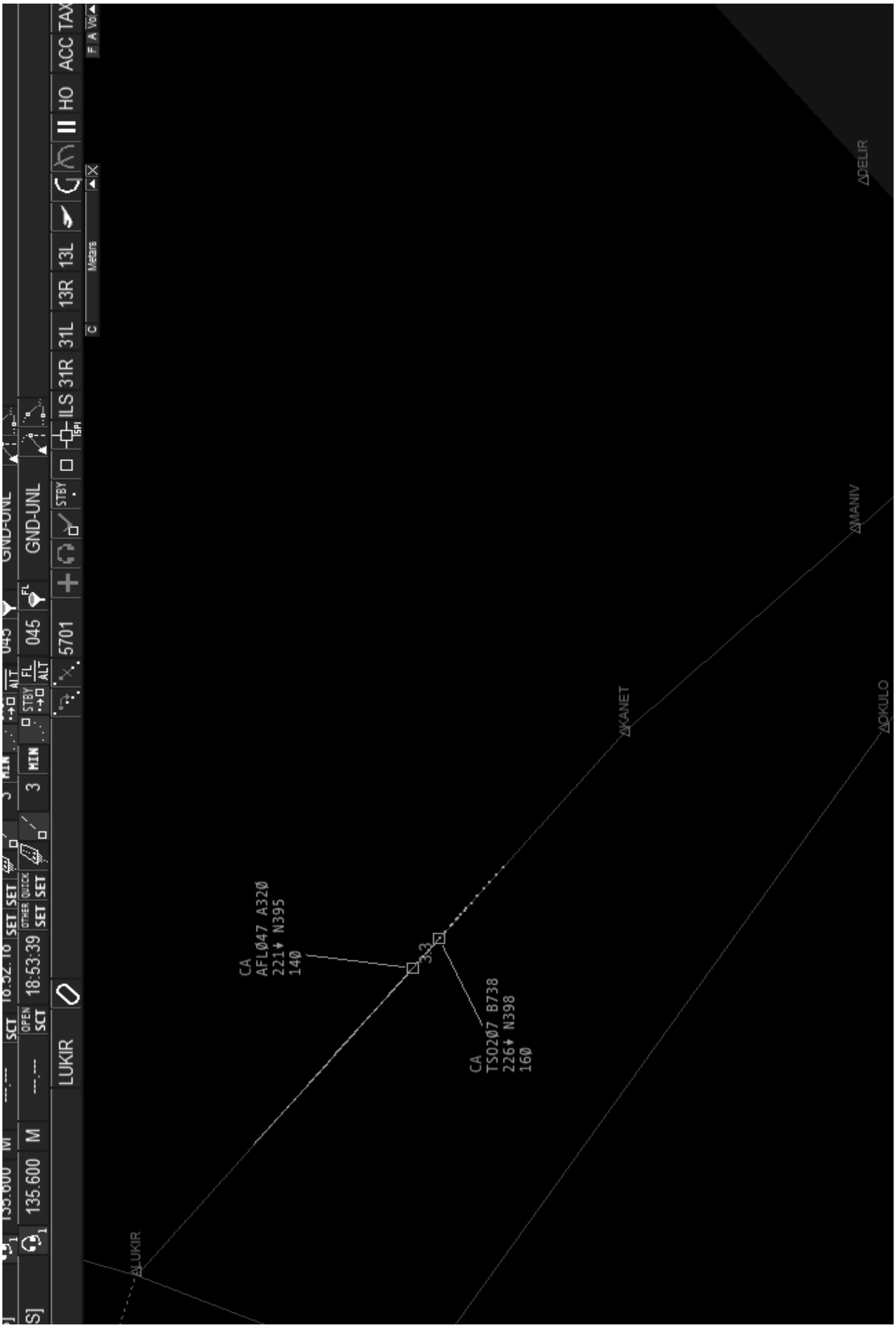

Fig. 4. Near miss which occurred in the area of responsibility of Saint-Petersburg ATC center (altitudes are in feet, velocity is in knots, distance is in nautical miles)

It should be noted that among the professional ATCs, some deviations in danger estimations were noticed; in particular, the estimations of the AC danger made by air traffic controller #20 from Rostov ATC center stand out against the rest of the estimations (Table 4).

5. RESULTS AND DISCUSSION

The complex approach to the settlement of the problem of the AC danger estimation objectification is the most perspective as in the majority of other cases. The simplified block diagram of the suggested algorithm implementing this approach is represented in Fig. 5. In this way, the theoretical prediction of the aircraft collision probability is combined with the expert approach to the occurred AC danger estimation.

If the maximum interval $\tilde{\tau}_{j\ \max}$, beyond which we consider the probability of an aircraft collision to be negligible, some step Δ_τ, some range of the aircraft velocities $[V_{max}, V_{min}]$ and their step of change Δ_V, then one can converge all the AC infinite manifold to a large but finite number.

To determine the probability of aircraft collision the Reich model [6] and its modifications were developed. However, the principal disadvantage of Reich model is a number of limitations imposed on it. The most important of them are as follows [6]:

● the flight of an aircraft is going without the ATC radiolocation control;

● it is impossible to get any external information with respect to errors in distinguishing the position of an aircraft for a pilot to make the corresponding heading corrections;

● no maneuvers on avoidance are made based on visual or instrumental detection of a dangerous near miss on board of conflicting aircraft.

There are other restrictions but they are less important for our problem. The probability of an aircraft collision (P_C) can be determined from the following:

$$P_C = P_{VP}\left(2R\int_{\bar{S}_{t0}}^{\bar{S}_{t1}} C(\bar{S}_t)d\bar{S}_t\right)\left(1+\frac{R\pi\left|\tilde{V}\right|_{V=0}}{4h}\left(\frac{\left\|d\bar{S}_t\right\|}{dt}\right)^{-1}\right), \tag{6}$$

where P_{VP} is the probability of a partial covering in a vertical plane (detailed consideration of its determining is discussed in [6]); $\bar{S}_t$ is a vector characterizing the position of aircraft relative to each other at the moment of time t; $C(\bar{S}_t)$ is the probability density of a partial overlap; R is the radius of a critical volume equal to two radii of described aircraft spheres; $\left|\tilde{V}\right|_{V=0}$ is the average vertical velocity ratio at the moment of collision in a vertical plane; h is a vertical size of an aircraft.

It is quite obvious that these limitations make the usage of Reich model practically unacceptable for our purposes if one tries to calculate probability of the aircraft collision, although the attempts to analyze HF influence were made before in [28]. Assuming the limitations of Reich model are held, one can determine conditional probability of aircraft collision. Consequently, we can rank AC in order of the danger level, then with expert estimations and their interpolations the danger estimation for every AC can be obtained.

6. CONCLUSIONS

1. The problem of objectification for the danger subjective estimation of abnormal cases in air traffic control is of high importance.
2. There are no satisfied methods of objectification of the AC danger estimation in ATC at the moment, and it is necessary to find new approaches on this subject.
3. Obviously, the problem of inadequacy for the danger estimation made by an ATC exists. Although the danger estimation by expertise could provide inaccurate results for the AC danger estimation φ_O, the inverted results are apparently much worse. At least 12% of respondents are in

disagreement with the rest of 88% on the estimation of the AC danger. Thus, one confirms that the usage of expert estimations for the AC danger estimation objectification, even in its simplified form, is an acceptable approach at the moment.

4. A combined approach seems to be the most promising to solve the problem of the AC danger estimation objectification. By this approach, the theoretical estimation of the aircraft collision probability is coupled with the expert approach to perform AC danger estimation.
5. If one determines the conditional probability of the aircraft collision, i.e. the probability of collision under conditions that the limitations imposed by the Reich model hold, we can rank AC in the order of a danger level and then by expert estimations and their interpolation get the danger estimation of each AC.
6. The estimation data can be used for ATC EWC evaluation as well as for their distance training on abnormal cases. The corresponding exercise can be easily implemented in a form of a computer program in which a trainee is offered different AC for danger estimation. The received results and actions on aircraft collision prevention are compared with the standard ones.

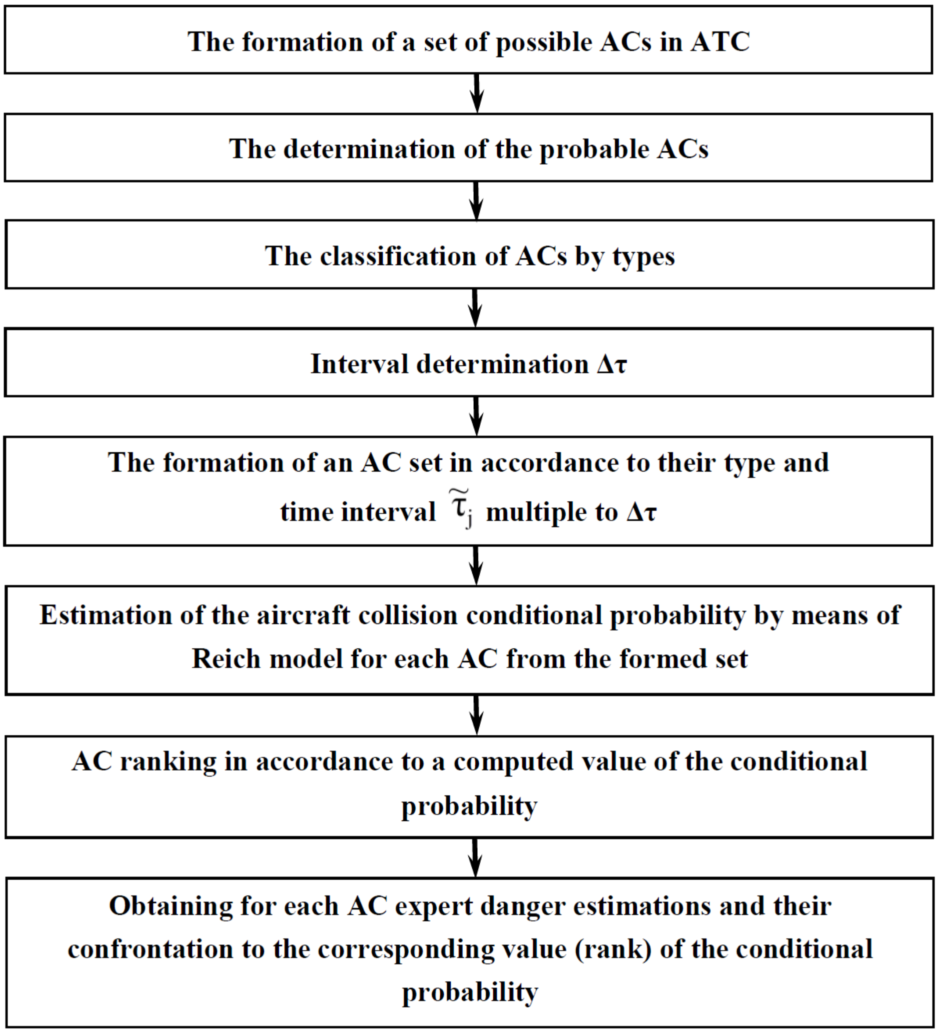

Fig. 5. A simplified flow-chart diagram implementing the combined approach to the AC danger estimation in ATC

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