

**Air situation situations that determine the quality of operation and efficiency of UAS**

*Airborne conditions have a significant impact on the quality and efficiency of UAS. Influencing factors include the internal attributes of the crew-aircraft system, the efficiency of the air traffic system, non-systematic factors, and positional parameters and constraints.*

Situations in the air navigation system (ANS) are formed as a result of direct influences on its subsystems and their operating conditions. Based on the structure and connections of the ANS, these influences can be determined by individual subsystems, which are characterized by: internal properties of the crew-aircraft system related to the functional efficiency of the crew and the functional efficiency of the LA; efficiency of the air traffic system, in particular, the efficiency of the ATC system circuit and the efficiency of radio navigation systems; the level of influence of non-system factors (external conditions); parameters of movement and position of the LA in space, as well as a number of restrictions.

During operation, there are certain deviations from the optimal values of the system parameters, which leads to a range of situations. Moreover, the complexity of situations is determined by the sequence of events. The previous event is considered as a cause in relation to the subsequent event caused by it. In the process of development of a negative phenomenon, in general, there may be several causes that consistently complicate the situation and eventually lead to an aviation accident.

The trajectories of aircraft movement are uniquely defined at some point in time  $t$  by three position coordinates and three velocity components:

$$\bar{X} = (x_1, x_2, x_3, \dot{x}_1, \dot{x}_2, \dot{x}_3), \left\{ \dot{x}_i = \frac{dx_i}{dt}, i = \overline{1, 3} \right\} \quad (1)$$

Let's select a pair of aircraft from the flow of aircraft, the position of each of which will be characterized by the longitudinal coordinate  $x = x_1$ , height  $H = x_2$  and lateral component or deviation  $y = x_3$ . Let us assume that at some point in time  $t$  there are true values of the observation coordinates  $(x_1, y_1, H_1)$  of the position of the first aircraft and  $(x_2, y_2, H_2)$  – of the second aircraft. In this case, we assume that there is a convergence of aircraft along the  $OX$ :  $\frac{d|x_2 - x_1|}{dt} < 0$ , i.e., the distance between the aircraft along the  $OX$  axis decreases.

It is in this case that it is necessary to analyze situations, since with a decrease in the value  $|x_2 - x_1|$ , aircraft can threaten each other with a collision. Therefore, in order to assess the degree of danger of situations that arise when aircraft approach at a particular coordinate, it is necessary to introduce a measure that would allow characterizing these situations. As such a measure, we will introduce a metric in the three-dimensional Cartesian coordinate space that describes the distance of the aircraft (Fig. 1).

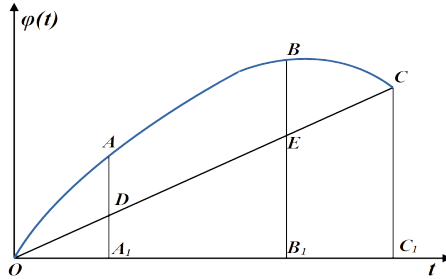


Fig.1. Toward a justification of the UAV air situation metric

After entering the situation metric, a spectrum of situations is built (Fig. 2).

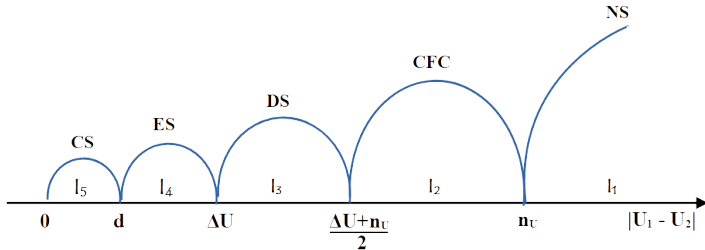


Fig.2. Development of situations along one coordinate: NS- normal situation (НС - нормальна ситуація), CFC - complicated flight conditions (УУП - ускладнення умов польоту), DS - difficult situation (СС - складна ситуація), ES - emergency situation (АС - аварійна ситуація), CS - catastrophic situation (КС – катастрофічна ситуація)

The principle of their construction is as follows. Consider the range of situations for two airplanes (Figure 3):

a) Two airplanes are flying in neighboring corridors. One is searching, the other maintains a given flight path along the  $x$ -axis. Situations are generated for the coordinates  $x_2 - x_1, y_2, H_2$ . We have three situations ( $S_{x_{12}}, S_y, S_H$ ). The global situation is described by the metric (1).

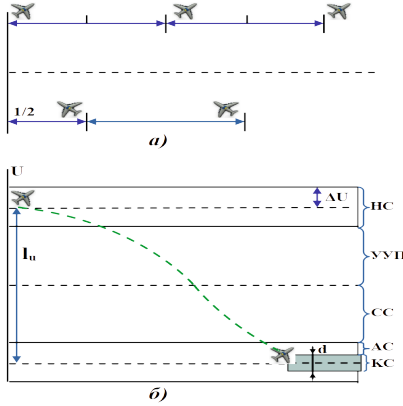


Fig.3. The global situation is described by the metric

b) Two airplanes are flying in neighboring corridors and both are searching. The situations are worked out for the coordinates  $\mathbf{x}_2 - \mathbf{x}_1, \mathbf{y}_2 - \mathbf{y}_1, \mathbf{H}_2 - \mathbf{H}_1$ . In this case, the three situations are as follows:  $(\mathbf{S}_{x_{12}}, \mathbf{S}_{y_{12}}, \mathbf{S}_{H_{12}})$  and the global situation is described by the metric (1).

c) Two airplanes are flying in the same air corridor along the  $\mathbf{X}$ -axis. The situations are developed for the difference  $\mathbf{x}_2 - \mathbf{x}_1$  and have the form  $(\mathbf{S}_{x_{12}}, 0, 0)$ .

Let's consider a range of situations for two oncoming streams. The danger of mutual collision exists for pairs of aircraft  $(\mathbf{L}_i, \mathbf{D}_i), i = \overline{1, n}$ , as well as for pairs of aircraft  $(\mathbf{L}_i, \mathbf{L}_{i+1}); (\mathbf{D}_i, \mathbf{D}_{i+1}), i = \overline{1, n-1}$ :

a) For the pairs  $(\mathbf{L}_i, \mathbf{D}_i), i = \overline{1, n}$  we have a spectrum of situations  $\mathbf{S}_x(\mathbf{L}_i, \mathbf{D}_i), \mathbf{S}_y(\mathbf{L}_i, \mathbf{D}_i), \mathbf{S}_H(\mathbf{L}_i, \mathbf{D}_i), i = \overline{1, n}$ . Here, the situation  $\mathbf{S}_x(\mathbf{L}_i, \mathbf{D}_i)$  is determined by the difference of the observed coordinates  $\mathbf{x}(\mathbf{L}_i) - \mathbf{x}(\mathbf{D}_i)$ . As for the situations  $\mathbf{S}_y$  and  $\mathbf{S}_H$ , there are two possibilities for them:

- develop situations based on the differences  $\mathbf{y}(\mathbf{L}_i) - \mathbf{y}(\mathbf{D}_i)$  or, respectively, on the differences  $\mathbf{H}(\mathbf{L}_i) - \mathbf{H}(\mathbf{D}_i)$ ;

- to develop situations  $\mathbf{S}_y(\mathbf{L}_i), \mathbf{S}_y(\mathbf{D}_i)$  and  $\mathbf{S}_H(\mathbf{L}_i), \mathbf{S}_H(\mathbf{D}_i)$  for each aircraft separately, respectively. In this case, we alternately assume that one of the aircraft  $(\mathbf{L}_i, \mathbf{D}_i)$  is at risk, and the other is flying along a given trajectory. This approach to situations corresponds to n-a for two aircraft.

b) For pairs  $(\mathbf{L}_i, \mathbf{L}_{i+1})$  we have a spectrum of situations  $\{\mathbf{S}_x(\mathbf{L}_i, \mathbf{L}_{i+1}), i = \overline{1, n-1}\}$ . Here,  $\mathbf{S}_x \in \{\mathbf{S}_1, \dots, \mathbf{S}_8\}$ ,  $\mathbf{S}_1$  is the,  $\mathbf{S}_2$  - the UUP, etc., and  $\mathbf{S}_8$  is the CS at the  $\mathbf{X}$ . The situations here are resolved by the difference of the observed coordinates  $\mathbf{x}(\mathbf{L}_i) - \mathbf{x}(\mathbf{L}_{i+1})$ .

For the pairs  $(\mathbf{D}_i, \mathbf{D}_{i+1})$ , we also have a spectrum of situations  $\{\mathbf{S}_x(\mathbf{D}_i, \mathbf{D}_{i+1}), i = \overline{1, n-1}\}$ , which are resolved by the difference  $\mathbf{x}(\mathbf{D}_i) - \mathbf{x}(\mathbf{D}_{i+1})$ .

Thus, the observed flows are described by the following number of situations:

$$(n-1) + (n-1) + n - 2nK_n = (3n-2) = 2nK_n$$

Here

$(n - 1)$  – the number of situations along the  $x$  -coordinate for aircraft of the same stream;

$n$  – the number of situations along the  $x$  -coordinate for pairs of aircraft of both streams flying towards each other;

$2nK_n$  – the number of the same situations in the  $y$  and  $H$  coordinate.  $K_n = 1$ , if the situations  $S_y(L_i, D_i), S_H(L_i, D_i)$  are worked out by coordinate differences;

$K_n = 0$ , if situations  $S_y(L_i, D_i)$  are split into two situations  $S_y(L_i), S_y(D_i)$ , and situations  $S_H(L_i, D_i)$  are also split into two situations  $S_H(L_i), S_H(D_i)$ , and the processing is carried out as described for the second case.

The considered spectrum of situations fully characterizes the quality of UAS functioning in ANS and determines their effectiveness. To assess this efficiency, it is necessary to develop an appropriate generalized criterion.

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