FLIGHT SAFETY AS CONSIDERED IN PROBABILISTIC TERMS

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Abstract

In this paper we concerned some probabilistic aspect of flight safety. We will presented methodology of probabilistic calculations of successful and safe completion of a flight.

1 Probability of safety flight

Depending on the degree of hazard that puts safe continuation of a flight at risk caused by undesired events, the arising circumstances that endanger safe operation of aircrafts may be subdivided into: sophisticated (complex), dangerous, breakdowns and catastrophic failures. These may lead to an avionic accident. Investigation for a reason of an avionic accident sometimes requires the calculation of the probability of successful and safe completion of a flight. Such calculation can be carried out through analysis of a graph that represents potential situations during an aircraft journey (Fig. 1).

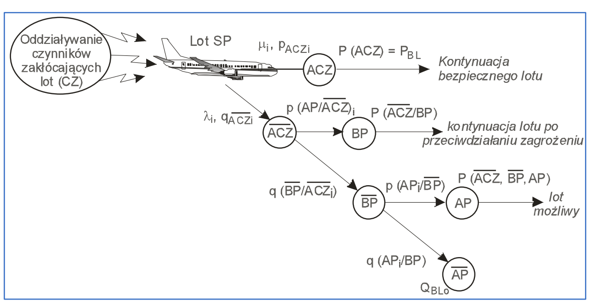

Fig. 1. Graph of possible situations that potentially may occur during an aircraft flight

The graph depicts the process of a flight with transitions from a specific state to a subsequent one (nodes-circles). For further considerations the following denotations of various situations (system status) were adopted: ACZ and $\overline{ACZ}$ – the state when a specific flight-disturbing factor appears or not, BP and $\overline{BP}$ - state when the board crew is able to neutralize (counteract) the flight disturbing factor, AP and $\overline{AP}$ – the final state of successful or unsuccessful completion of the flight. Probability of a safe flight P_{BLo} depends of the progress of events, and can be expressed by the following formula:

$$P_{BLo}(t)=\prod_{i=1}^{N}\left\{p_{ACZ_i}(t)+\left[1-p_{ACZ_i}(t)\right]p_i\left(BP/ACZ_i\right)\right\} \quad (1)$$

where (i = [1, N]) are possible factors that may disturb aircraft flights.

The expression (1) contains probability values with the indication that such probabilities may be (and actually are) the functions of time.

If reasons for an avionic accident are limited to the number of M possible faults, defects and unserviceability circumstances whereas the board crew (a pilot) is able to counteract such events (neutralize, refurbish) or not and the event may occur with the componential probability of p_{ui}, the probability of a safe flight can be calculated in the following way:

$$P_{BLo}(t)=\prod_{j=1}^{M}\left\{p_{u_j}(t)+\left[1-p_{u_j}(t)\right]p_j\left(BP/\overline{USZ}_i\right)\right\} \quad (2)$$

where: $p_j(BP/\overline{USZ}_j)$ – is a conditional probability of correcting measures after the j^{th} fault or defect has occurred.

In practice, the total of possible major (decisive) unfavourable factors that initiate undesirable events can be organised into five most essential groups, to which suitable probabilities of reliability (P) and unreliability (Q) can be attributed. These are as follows:

1. Flying/handling qualities, aerodynamic characteristics (stability, strength, flatter, etc.) of aircraft:
P_A – probability that flying/handling qualities, aerodynamic characteristics remain within suitable, permissible limits;
Q_A – opposite probability (Q_A = 1 - P_A).
1. Reliability characteristics of an aircraft
P_R – probability of trouble-free performance of the aircraft;
Q_R – probability that a failure mode occurs to the aircraft.
2. Characteristics of trouble-free performance of the organisational environment (ground staff, flight management, overhaul/repair workshops), with no mistakes by the aircrew
P_N – probability of trouble-free performance of the organisational environment. In practice, this probability comprises the following components: P_{NO} – of ground staff, overhauls, repairs, as effect of error-free or incorrect operations; P_{NS} – ground systems of flight protection;
Q_N – probability of failure to the above-mentioned components.
3. Aircraft-flying skills of the aircrew (pilot) manifested with the ability to error-free flying and operating the aircraft:
P_P – probability of error-free performace/actions of the aircrew;
Q_P – probability that the aircrew make error(s).
4. Natural and weather characteristics, the so-called external factors (storm, hail, birds, etc.)
P_Z – probability of favourable conditions;
Q_Z - probability of unfavourable external conditions. The probability of performing a safe flight P_{BLo} can be expressed with the following dependance [1]:

$$P_{BLo} = P_A\, P_R\, P_N\, P_P\, P_Z \qquad (3)$$

where:

$$P_A = \prod_{1=1}^{S}\left[P_{As} + Q_{A_s} P_s(KR/AW)\right] \qquad (4)$$

$$P_R = \prod_{i=1}^{I}\left[P_{R_i} + Q_{R_i} P_i(KR/AW)\right] \qquad (5)$$

$$P_N = \prod_{j=1}^{J}\left[P_{N_j} + Q_{N_j} P_j(KR/AW)\right] \qquad (6)$$

$$P_P = \prod_{k=1}^{K}\left[P_{P_k} + Q_{P_k} P_k(KR/BŁ)\right] \qquad (7)$$

$$P_Z = \prod_{l=1}^{L}\left[P_{Z_l} + Q_{Z_l} P_l(KR/AW)\right] \qquad (8)$$

$P_s(KR/AW)$, $P_i(KR/AW)$, $P_j(KR/AW)$, $P_l(KR/AW)$ means the conditional probability of crew correction (*KR*) of *s*-th troubles of aerodynamic characteristics, and aircraft performance, *i*-th flying vehicle reliability malfunction, *j*-th malfunction of ground equipment, *l*-th influence of unfavorable conditions leading to malfunction (*AW*); $P_k(KR/BL)$ conditional probability of crew correction of *k*-th error (or mistake) (*BL*).

2 Conclusions

If appropriate values of transition intensities (λ_i, μ_i) are assigned to individual transitions from one state to another (Fig. 1) for various i^{th} disturbing factors (i = [1, N]), it is possible to draw up differential equations that define probabilities P_{BLo} and take account for probabilities of individual events and intensities of their occurrences.

References

[1] Barlow R. E., Proschan F.: *Statistical Theory of Reliability and Testing Probability Models.* Wyd. Holt, Rinehart and Wiston, NY, 1975

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