

**THE QUALITY OF BEING ABLE TO OPERATE SAFELY
– AN IMPORTANT PROPERTY OF SAFE
PERFORMANCE OF A AIR MISSION**

**BEZPIECZNOŚĆ – WAŻNA WŁAŚCIWOŚĆ
BEZPIECZNEJ REALIZACJI MISJI LOTNICZEJ**

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Abstract: *The quality of being able to operate safely (S, in Polish - bezpieczeńność) and the quality of being hazard-prone (Z, in Polish – zagrożeniowość, zagrożalność), Z being the opposite of S, are important properties of any maritime vessel and/or aircraft, i.e. any engineering system/device (UT). The rates W_S and W_Z considered in terms of probability and remaining within the $[0, 1]$ interval are measures of these properties. High value of W_S enables the engineering system/device (UT) to be operated with the possibly maximum safety. The sum of W_S and W_Z is one (unity), whereas the product thereof satisfies the following condition: $W_S \times W_Z \leq 1$. The derived equation of indeterminacy points out to the fact that any increase in the value of W_S by subsequent increments ΔW_S , which makes the W_S approach the limit of unity, demands ever greater amount of power and abilities, i.e. energy (expenses).*

Keywords: *safety*

Streszczenie *Bezpieczność (S) i zagrożeniowość (Z) – jako przeciwieństwo bezpieczeństwa – są ważnymi właściwościami statku morskiego, statku powietrznego – każdego urządzenia technicznego (UT). Ich miarami są wskaźniki W_S i W_Z rozważane w kategorii prawdopodobieństwa zawierają się w przedziale $[0,1]$. Wysoka wartość W_S umożliwia użytkowanie UT z możliwie największym bezpieczeństwem. Suma W_S i W_Z wynosi jeden, a iloczyn spełnia warunek: $W_S \times W_Z \leq 1$. Wyprowadzone eksploatacyjne równanie nieoznaczoności wskazuje na fakt, że zwiększanie wartości W_S o kolejne przyrosty ΔW_S zbliżające W_S do granicy „jeden” wymaga coraz większych nakładów energii (kosztów).*

Słowa kluczowe: *bezpieczeństwo*

1. Introduction

A maritime vessel and an aircraft show some similarities as far as their properties are concerned. Some symbiotic relationships between a maritime vessel and an aircraft have been illustrated in Fig. 1. The quality of being able to operate safely (in Polish – bezpieczeńność¹) is one of the above-mentioned properties. Safe performance of any maritime or air mission highly depends on the value of safeness, including the technical safeness of the ship's structure. Safety is also affected by environmental factors and a human factor. Safeness is most often defined as a property (a characteristic, i.e. a distinguishing quality, relative in its nature) which assures that the structural arrangement of the ship (including the ship's equipment) is maintained in order to be safely operated. In [3], safeness has been defined as the opposite of the dangerousness (i.e. the quality of not being safe). For the needs of this paper, safeness (*S*) is the antonym of (*Z*) – the quality of being hazard-prone (in Polish – zagrożalność).



*Fig. 1. One of the US aircraft carriers (photo USA)
and the airplane A-380 (photo Airbus)*

¹ English term ‘safeness’ meaning the quality of being safe may reflect the idea of ‘bezpieczność’, to some extent at least, and will be used hereinafter for this Polish term

Safeness is a derivative of the assumed structure of any engineering system/device (*UT*) reliability or, rather, unreliability thereof [2], maintainability, i.e. the ease with which the *UT* can be refurbished/restored (in particular, throughout the period of operational use of the *UT*), etc. The issue can be approached in a more general way while following the operational and maintenance events [1].

2. Operational and maintenance events

Operational and maintenance events within some operational/maintenance space-time continuum can be best described by means of the calculus of probabilistic phenomena. This straightforward leads to the statement that the existence of the so-called spheres of the deterministic chaos is quite possible. Another fact for the existence of such possibility is that any engineering object can be described with at least two states, i.e. the 'fit-for-use' state (in other words, the state of being serviceable) and the 'unfit-for-use' state (in other words, the state of being unserviceable), which proves to be sufficient for the existence of chaos. This statement enables operational and maintenance events to be described in some specific way, trajectories of situations to be determined, and desired trajectories and properties thereof to be searched out.

From the point of view of various subsystems of operation and maintenance of *UTs* (i.e. operational use, servicing, overhaul, storage, etc.), the operational and maintenance events, the location, the operational and maintenance distances, and time within the operational and maintenance space do not show the same universal features.

In real systems of *UT* operation and maintenance (*SE*), any information on the activation of operational and maintenance events comes only after some time to find that the system of *UT* operation and maintenance has been already involved in some new operational and maintenance situation. Any information on the system of *UT* operation and maintenance always refers to operational and maintenance events from the past. While this information is processed and analysed, the system of *UT* operation and maintenance is already in some other state, with difference resulting from the rate the operational and maintenance events proceed within the operational and maintenance space (*PE*).

In our considerations on the operation and maintenance we are interested in some specific engineering object (*OT*) and its condition. Conditions (states) of engineering objects determine our capability to perform and accomplish some tasks by means of some specific operational and maintenance event, when some operational and maintenance power and abilities (energy) (*E*) is used or reproduced (stored). An operational and maintenance event is what takes place at some specific point of the *n*-dimensional operational and maintenance (phase) space and within some specific time interval. To describe such an event, one should give space-and-time coordinates and operational and maintenance properties of the *UT*. These coordinates determine the location of an operational and maintenance event (*ZE*) within the space-time continuum, $n + 1 = N$ -dimensional. The *n* itself sets dimensions of the space whereas the unity (the 1) extends it on the account of time.

3. Relationship between safeness and outlays

Safeness - the quality of being able to operate safely (S) and the quality of being hazard-prone (Z), Z being the opposite of S , are important properties of any maritime vessel and/or aircraft, i.e. any engineering system/device (UT). Both manifest themselves throughout the process of operation and maintenance. The rates W_S and W_Z considered in terms of probability and remaining within the $[0, 1]$ interval are measures of these properties. The probabilistic description of operational and maintenance states and events suggests the existence of quantised states within the operational and maintenance space-time continuum. This allows us to postulate the so-called principle of operational and maintenance indeterminacy, according to which the product of a change in an operational and maintenance measure (e.g. safeness, ΔS) and a change in the operational and maintenance power and abilities (energy) (ΔE) should be higher than some operational and maintenance parameter L .

In modern quantum mechanics that describes behaviour of quantum systems - delivering, within the limits, description by classical mechanics – parameters of particle states in terms of probability are obtained. In exactly the same terms, i.e. in terms of probability described are features of operational and maintenance events. Great similarity in the mathematical description may appear here. And sure enough, one can derive the principle of indeterminacy, of universal importance to the science of systems operation and maintenance [1], described with expressions (3.1). These expressions determine the so-called mathematical relationships in the principle of operational and maintenance indeterminacy. This principle connects the suitably allocated feature (property), e.g. safeness, with the operational and maintenance power and abilities (energy) or the expense of change into an equation where the specific operational and maintenance parameter L exists. This parameter, i.e. L , is defined (by units of energy, or cash items) depending on the losses that happen to occur in the process of UT operation and maintenance.

$$\begin{aligned}\Delta S \times \Delta E &\geq L_E \\ or & \\ \Delta S \times \Delta C &\geq L_C\end{aligned}\tag{1}$$

where: S - safeness in terms of probability (W_S): of being unfit-for-use (unserviceable), of danger/threat/hazard, that the task remains unaccomplished, of reliability, safety, readiness; closely related to the following dependence: $S = 1 - Z$; E – operational and maintenance energy, and C – corresponding equivalent expense; L_E , L_C – operational and maintenance parameters (as evaluated by the operational and maintenance energy, and generalised cost, respectively).

Relationships (1) express the fact that there are relationships between the expenditure of operational and maintenance energy (quite often partial energy, in

particular when referred to reliability, safety, readiness, and even to the process of diagnosing, etc.), and the level of safeness S already reached. These relationships point out to what follows: as the value of safeness S comes closer - within the limit - to the unity (the 1), there become a need for greater deliveries of operational and maintenance energy ΔE of equivalent cost ΔC (Fig. 2).

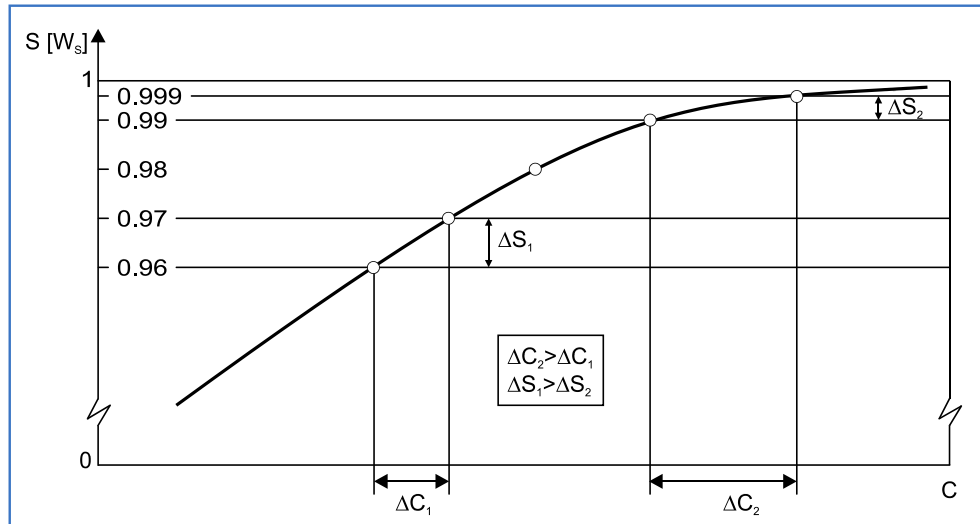


Fig. 2. Change in safeness S against generalised operational and maintenance cost C

4. Concluding remarks

Information on the behaviour of time-dependent systems refer to, e.g. issues of energy distribution within the energetic 'ladder' of the activated object. Such situation is usually represented by an engineering object (OT) or operational and maintenance system (SE), which may be in motion while performing tasks within any operational and maintenance subsystem. What we have to deal with in this case is some change in the operational and maintenance energy E within some interval between E_{\max} and E_{\min} (operational use) or E_{\min} and E_{\max} (overhaul). The process of operation and maintenance proceeds in a 'chaotic' way, although it seems to be planned. Performance of operational-use-dedicated tasks is usually allocated to some specific but discretionary items within a set of engineering objects, the items mentioned being subject to laws of reliability and other probabilistic ones. In the future, they are expected to behave in the static way.

A high value of W_S enables operational use of any UT with possibly highest safety. The sum of W_S and W_Z amounts to one (unity), whereas the product thereof satisfies the following condition: $W_S \times W_Z \leq 1$. The derived equation of indeterminacy points out to the fact that any increase in the value of W_S by subsequent increments ΔW_S , which makes the W_S approach the limit of unity, demands ever greater amount of power and abilities, i.e. energy (expenses).

5. References

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