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MEMORANDUM FOR: The Director of Central Intelligence

FROM : John N. McMahon
Deputy Director for Operations

SUBJECT : MILITARY THOUGHT (USSR): Taking into Account the Reliability of Equipment When Planning the Employment of Rocket Troops

1. The enclosed Intelligence Information Special Report is part of a series now in preparation based on the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal 'Military Thought". This article demonstrates how statistical probability methods can be applied to the process of missile preparation in order to compensate for malfunctions and delays. Since the point is to illustrate the methods, the actual figures used in the article are more or less arbitrary. This article appeared in Issue No. 2 (87) for 1969. [redacted]

2. Because the source of this report is extremely sensitive, this document should be handled on a strict need-to-know basis within recipient agencies. For ease of reference, reports from this publication have been assigned [redacted]

[redacted]

John N. McMahon

[redacted]



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# Intelligence Information Special Report



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SUBJECT

MILITARY THOUGHT (USSR): Taking into Account the Reliability of Equipment When Planning the Employment of Rocket Troops

SOURCE Documentary

Summary:

The following report is a translation from Russian of an article which appeared in Issue No. 2 (87) for 1969 of the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal 'Military Thought". The authors of this article are Lieutenant Colonel V. Krasilev, Candidate of Military Sciences, and Engineer Major V. Panov, Candidate of Technical Sciences. This article demonstrates how statistical probability methods can be applied to the process of missile preparation in order to compensate for malfunctions and delays. Since the point is to illustrate the methods, the actual figures used in the article are more or less arbitrary.

End of Summary

[redacted] Comment:

The SECRET version of Military Thought was published three times annually and was distributed down to the level of division commander. It reportedly ceased publication at the end of 1970. [redacted]

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# Taking into Account the Reliability of Equipment When Planning the Employment of Rocket Troops

by

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Engineer Major V. PANOV, Candidate of Technical Sciences

At the present time, the assessment and calculation of the reliability of armament are done principally only during the performance of technical tasks. At the same time, it is becoming more and more obvious that it must be assessed and taken into account also during the planning of combat actions. This is especially important for missile systems, which are aggregates of complex technical systems. Presently, as we know, the staffs of the rocket troops and artillery either do not take the actual reliability indices of armament into account at all or they consider them only in rough approximation. Yet practice has established that random malfunctions are in fact an inevitable occurrence both during the preparation of missiles for a launch and during their flight to the target. Obviously, to rule out the possible consequences of the occurrence of armament malfunctions in a combat situation, definite reserves must be provided for. It must be said that so far no suitable scientifically valid methodology of calculating the reliability indices has been worked out to apply to operational-tactical and tactical missile systems. It is the purpose of this article, along with examining the problem of reliability of missile systems, to propose a methodology for calculating it when planning the combat employment of the rocket troops of the ground forces.

The reliability of missile systems is understood as their capability to fulfil the assigned functions with preservation of technical indices in the process of operation and combat employment (barring damages by means of destruction the enemy may employ). Reliability is described as the trouble-free operation, repairability, storage capability, and durability of the missile systems.

A high level of reliability must be provided for already during the development (designing) of systems, ensured during their production, and maintained during operation.

The main elements of missile systems are the missiles (delivery missiles with warheads), the launchers (systems of units and mechanisms that ensure the pre-launch preparation and launch of missiles), and the ground equipment meant for checking, assembling, fueling, transferring, and transporting missiles, without this being broken down into units and individual mechanisms but with regard for how these are grouped in the missile technical units in keeping with the established technological processes of missile preparation. The allocation of the main elements in a missile system is done with regard for the specific nature of each system.

Malfunctions of some or the other elements in the course of operation and combat employment (depending on whether or not they can be remedied) can lead to various consequences -- delay in the preparation of missiles, reduction of the effectiveness of missile strikes, or non-fulfilment of individual combat tasks. What first and foremost affects the combat effectiveness of rocket troops is the possibility of the occurrence of malfunctions during the preparation and use of missiles (delivery missiles with warheads) directly intended for the fulfilment of combat tasks.

Accordingly, the reliability of a missile system on the whole is assessed by the indices defining the reliability of their [sic] elements during the deployment of missile and missile technical units into battle formation and during the preparation of missiles at the launch sites and the sites of the missile technical units, as well as by the indices that define the reliability of the missiles themselves during launch and in flight.

Reliability indices can be general or particular. The general indices describe the level (degree of success) of missile passage through a definite stage of preparation or combat employment, and the particular indices describe the probability of individual peculiarities of the missile or the other elements of the system appearing, as determined by their level of reliability.

In planning, consideration must be given to the indices whose quantitative values express the degree of reliability of the elements of the missile systems at the stages of preparation and combat employment of missiles to be examined (in each specific case).

If the preparation of missiles in missile technical units is done in one stage, then consideration of the following groups of indices may be required.

Indices describing the reliability of missiles during launch and in flight.

General index: probability of trouble-free functioning of the missile during launch and in flight.

Particular indices: probability of trouble-free launch of the missile, probability of accident-free flight of the delivery missile and trouble-free operation of the warhead, probability of no increased deviation of the missile from the point of aim, and average value of the missile deviation from the point of aim in the case of increased deviation.

Indices describing the reliability of the elements of the missile system during the preparation of missiles at the launch sites and technical sites.

General indices: probability of normal preparation* of one missile at the launch site (technical site), probability of the occurrence of a remediable malfunction of the missile or launcher at the launch site (of the missile, launcher, or ground equipment at the technical site) during the preparation of one missile, probability of the occurrence of a non-remediable malfunction of the missile or launcher at the launch site (of the missile, launcher, or ground equipment at the technical site) during the preparation of one missile, and average delay of the preparation of one missile because of a malfunction of the missile or launcher at the launch site (of the missile, launcher, or ground equipment at the technical site).

Particular indices: probability of trouble-free functioning of one missile during preparation at the launch site (technical site), probability of trouble-free functioning of the launcher during the preparation of one missile at the launch site (technical site), probability of trouble-free functioning of the ground equipment during the preparation of one missile at the technical site, probability of the occurrence of a remediable malfunction of the missile during preparation at the launch site (technical site), probability of the occurrence of a non-remediable malfunction of the missile during preparation at the launch site (technical site), probability of the occurrence of a remediable malfunction of the launcher during the preparation of one missile at the launch site (technical site), probability of the occurrence of a non-remediable malfunction of the launcher during the preparation of one missile at the launch site (technical site),

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* Normal preparation of a missile is understood as its preparation without more than the standard delay due to a malfunction of the missile itself or of the other elements of the system.

probability of the occurrence of a remediable malfunction of the ground equipment during the preparation of one missile at the technical site, probability of the occurrence of a non-remediable malfunction of the ground equipment during the preparation of one missile at the technical site, average delay of the preparation of one missile if it malfunctions at the launch site (technical site), average delay of the preparation of one missile if the launcher malfunctions at the launch site (technical site), and average delay of the preparation of one missile if the ground equipment malfunctions at the technical site.

Indices describing the reliability of the elements of the missile system during deployment of the missile and missile technical units (subunits) into battle formation: probability of normal (trouble-free) deployment of the launcher at the launch site (of the ground equipment at the technical site), probability of the occurrence of a remediable malfunction of the launcher during deployment at the launch site (of the ground equipment at the technical site), and probability of the occurrence of a non-remediable malfunction of the launcher during deployment at the launch site (of the ground equipment at the technical site).

The reliability indices to be taken into account when planning the combat employment of the rocket troops must be established for each type of missile system in accordance with its specific features of missile preparation and particularized in keeping with its accepted levels of combat readiness. Their quantitative values are determined according to the results of tests, of operation in the missile and missile technical units, and of missile launches at firing ranges. The trustworthiness of reliability indices will depend on how close the missile systems operating conditions under which they are obtained are to the conditions of a combat situation. Assessment of the accuracy of reliability indices can be done by establishing confidence limits (their numerical values) with a set confidence probability.* In assessing the reliability of the elements of missile systems in practice, one may take a confidence probability of $P_c = 0.95$.

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* By confidence probability ($P_c$) is understood that probability where the value obtained for an index is not less than the lower limit (lower confidence limit) nor greater than the higher (upper confidence limit).

To determine the quantitative value of a reliability index and its corresponding confidence limits, it is necessary to compute the value of the reliability index as the frequency of occurrence of an event (for instance, a remediable malfunction) or the mean arithmetic value (for instance, the average time delay in the preparation of a missile) and to determine the limits of the confidence interval of the value of the reliability index in accordance with the accepted confidence probability.

In this way, as a result of the processing of statistical data, one obtains mean quantitative values of the reliability indices and the confidence limits that describe the accuracy of the determination of these indices.

For the indices reflecting the reliability of missiles in the respective stages of preparation and employment, it should be indicated what preceding transportation distances the indices correspond to and how they will change depending on the transportation distances.

What are the problems connected with the planning of the combat employment of rocket troops during whose solution it is necessary to consider the reliability indices of the elements of the missile systems?

In our opinion, these problems will be the following: calculation of the required number of missiles (launchers) to hit the assigned enemy targets or of the possibilities of hitting the enemy targets with the available (allocated) missiles (launchers) and also of the time required for the rocket troops to prepare for carrying out combat tasks, determination of the necessary number of missile technical units to prepare the required (assigned) number of missiles in the established periods of time or of the capabilities of the available (allocated) missile technical units to prepare missiles in the established periods of time, and calculation of the time for preparing the assigned number of missiles with the available (allocated) missile technical units as well as of the time required for the missile technical units to prepare for carrying out tasks.

The calculations indicated underlie the solution of all problems connected with planning of the combat employment of rocket troops. They can be considered in general as quantitative (direct and inverse) as well as time problems.

In a direct quantitative problem, the requirement for elements of the missile system is determined according to the known volume, nature, time, or procedure for performing assigned tasks.

In an inverse quantitative problem are determined the capabilities of the available or allocated elements of the missile system to perform their regular (or assigned) tasks at the established time.

In time problems is calculated the time that missile and missile technical units require to prepare for the performance of tasks (or to perform them).

The procedure for calculating the reliability indices of the elements of a missile system in the solution of quantitative problems may be as follows.

In a direct problem, after determining the requirement $N_0$ for elements of the missile system without regard for reliability, one calculates the requirement R for reserve elements and the total number N needed to perform the assigned tasks when reliability is taken into account ($N = N_0 + R$).

In an inverse problem, on the basis of the available (allocated) number N' of elements of the missile system, one determines the number R' of elements which may malfunction and the number $N'_0$ of elements which may be used to perform tasks when the established reliability is taken into account ($N'_0 = N' - R'$).

If malfunctions are non-remediable or cannot be remedied in time, they cause such a reduction of the effectiveness of the missile system that they can be compensated for only through the allocation of reserve elements that ensure the performance of tasks in case of the malfunction of activated elements of the missile system.

The malfunction of one or the other element of a missile system is a random event, and non-remediable malfunctions of these elements, as experience shows, belong to the class of low-probability events. Therefore, to calculate the requirement of a missile system for reserve elements, one can use the laws describing the probability distribution of infrequent occurrences.

In connection with this, the probability of occurrence S of malfunctions of like elements of a missile system (for instance, only missiles or only launchers) and, consequently, the probability of the event

that R reserve elements will be required in order to perform the assigned tasks with $N_0$ like elements can be determined from Poisson's formula

$$P_{N_0}(S) = e^{-R_m} \frac{R_m^S}{S'},$$

where $R_m$ is the mathematical expectation of the average number of elements of a missile system with malfunctions, and
e is the base of natural logarithms.

However, when the operations to prepare or launch a missile are performed, there may be no malfunctions at all or it is possible that one, two, or more elements of the missile system may malfunction. Therefore, in order to determine the number of reserve elements, it is necessary to consider the probability of occurrence of any combination of possible events (S = 0, 1, 2, 3...).

The probability of no more than R like elements of a missile system having malfunctions, given a known probability q of the elements having malfunctions in one attempt, is equal to

$$P(R) = e^{-R_m} \sum_{S=0}^{R} \frac{R_m^S}{S'}.$$

This formula enables one to determine the relationship between the probable requirement of a missile system for reserve elements and the number of these elements.

From the results of analysis and calculations a working table can be compiled that enables one to determine the requirement for reserve elements with a set guaranteed probability of the performance of tasks* and, consequently, the necessary data for considering the reliability indices of the elements of missile systems when planning the combat employment of rocket troops.

| P | 0.70 | | 0.75 | | 0.80 | | 0.85 | | 0.90 | | 0.95 | | 0.97 | | 0.99 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_0$ | N | R | N | R | N | R | N | R | N | R | N | R | N | R | N | R |
| 1 | 3 | 1.1 | 2 | 0.9 | 2 | 0.8 | 2 | 0.7 | 2 | 0.5 | 1 | 0 | 1 | 0 | 1 | 0 |
| 2 | 4 | 2.0 | 4 | 1.7 | 4 | 1.4 | 3 | 1.0 | 3 | 0.8 | 3 | 0.5 | 3 | 0.2 | 2 | 0 |
| 5 | 9 | 4.0 | 9 | 3.2 | 8 | 2.8 | 7 | 2.0 | 7 | 1.6 | 6 | 0.9 | 6 | 0.7 | 5 | 0 |
| 10 | 17 | 6.4 | 16 | 5.2 | 15 | 4.5 | 14 | 3.5 | 13 | 2.6 | 12 | 1.6 | 11 | 0.9 | 11 | 0.5 |
| 20 | 32 | 11.3 | 30 | 9.4 | 28 | 7.7 | 26 | 6.0 | 25 | 4.3 | 23 | 2.5 | 22 | 1.8 | 21 | 0.9 |
| 30 | 46 | 15.9 | 44 | 13.4 | 41 | 10.8 | 39 | 8.1 | 36 | 5.9 | 34 | 3.3 | 33 | 2.3 | 31 | 0.9 |
| 40 | 61 | 20.2 | 57 | 16.8 | 54 | 13.6 | 51 | 10.5 | 48 | 7.4 | 45 | 4.2 | 43 | 2.9 | 42 | 1.2 |

After determining the requirement for elements of a missile system or the capabilities of the available (allocated) elements with the aid of this table, one may calculate that in 95 cases out of 100 the elements of the missile system will perform the assigned task (missiles, to hit the assigned enemy targets; launchers, to launch the required number of missiles; and ground equipment, to prepare the assigned number of missiles in the established period of time).

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* In compiling this table, the authors have taken a guaranteed probability of $\alpha = 0.95$. However, it should be kept in mind that such a high value of guaranteed probability for the fulfilment of combat tasks causes an elevated requirement for armament reserves. Therefore, when less crucial tasks are accomplished, it seems possible to allow a considerable reduction of the guaranteed probability value whereby the number of reserve elements will approximate the mathematical expectation of the number of malfunctions ($\alpha = 0.5$). Thus, the given table can be regarded as an example of the calculation of reserve elements for one chosen guaranteed probability value. (Editor's comment in the original)

When solving time problems, one must consider the time requirement for restoration of the elements of missile systems with remediable malfunctions. Here, as in the solution of quantitative problems, one determines how many elements can be prepared to perform tasks or can perform assigned tasks without delay, the possible number of elements with non-remediable malfunctions, and the expected number of elements with remediable malfunctions. It is ascertained, in addition, how the delay connected with restoring them will affect the time required for preparation or the performance of assigned tasks by the elements of the missile system. Let us now consider concrete examples of the procedure for solving these problems.

a) Calculation of reliability indices of the elements of a missile system when solving quantitative problems. Let us assume that it requires 10 missiles to hit assigned enemy targets, with no account taken of the reliability indices of the elements of the missile system. The requirement for missiles should be determined taking into account the reliability indices of the elements of the missile system in two cases: when hitting of the enemy targets must be done with a simultaneous launch of missiles and the delay due to remediable malfunctions of the missiles or the launchers amounts to several hours, and when combat tasks are fulfilled as the missile subunits become ready.

Solution. In calculating the number of missiles which must be prepared simultaneously for launching at launch sites, it is necessary to get the determined reliability indices (here and subsequently, the specific values of the reliability indices and the quantities obtained in using them are illustrative): the probability of normal preparation of one missile at a launch site is equal to 0.96, and the probability of normal functioning of the missile during launch and in flight is equal to 0.98.

In this case, the index of trouble-free operation of the elements of the missile system is determined as the product: $P = 0.96 \times 0.98 = 0.94$. From the table we find that, in order to ensure the guaranteed fulfilment of the combat tasks (with the given reliability index), 12 missiles must be prepared simultaneously for launching at the launch sites.

Under conditions where the combat tasks will be fulfilled as the missiles become ready for launching, one takes into account the possibility of using also those missiles that are found to have remediable malfunctions. If, for instance, the probability of occurrence of a remediable malfunction of the missile during preparation at the launch site is equal to 0.03, then the probability of trouble-free operation of the

missile system will be (0.96 + 0.03) x 0.98 = 0.97. Using the table, we establish that in this case 11 missiles should be prepared for launching at the launch sites.

When determining the number of missiles which must be prepared in the missile technical units (for the example under consideration), it should be kept in mind that there they can be prepared beforehand. In this case, only missiles with non-remediable malfunctions cannot be used. With a probability of the occurrence of a non-remediable missile malfunction during preparation in the missile technical units equal to 0.02, the probability of trouble-free functioning of one missile (or preparation of it with the elimination of malfunctions) will be 1 - 0.02 = 0.98. According to the table, the missile technical units will be required to prepare 13 missiles (to ensure the preparation for launching of 12 missiles at the launch sites) or 12 missiles (to ensure the preparation for launching of 11 missiles at the launch sites).

Thus, to ensure the guaranteed fulfilment of combat tasks with 10 missiles under the conditions here considered, 12 or 13 missiles have to be prepared in the missile technical units, and 11 or 12 at the launch sites.

b) Calculation of reliability indices of the elements of a missile system when solving time problems. Let us suppose that a missile technical unit (according to conditions of missile distribution and storage) can prepare eight missiles in 16 hours. It needs to be determined how much time is required to prepare this number of missiles when the reliability indices of the elements of the missile system are taken into account.

Solution. With a probability of normal preparation of a missile at the technical site equal to 0.90 and a probability of the occurrence of a non-remediable malfunction of the missile or ground equipment equal to 0.05 (the probability of its non-occurrence accordingly equals 1 - 0.05 = 0.95), judging from the data in the table it can be calculated that, out of eight missiles, six will be prepared in the normal time, one will be found to have a non-remediable malfunction, and one will have to be prepared with a delay (because of a remediable malfunction of the missile or ground equipment). The normal preparation time for one missile under the conditions here considered is two hours. Should a non-remediable malfunction occur, the preparation time for one missile doubles (it is necessary to detect the unserviceability of the given missile and carry out the preparation of another), i.e., it will be four hours. The time required to prepare one missile with a delay due to a remediable malfunction of the missile or ground equipment may come to three hours.

Thus, to prepare eight missiles will not require not 16, but $2 \times 6 + 4 \times 1 + 3 = 19$ hours.

So we are once again convinced that calculation of the reliability of missile systems is a necessary condition of the proper planning of the combat employment of rocket troops and will further the achievement of the required effectiveness of fulfilment of the combat tasks entrusted to them.