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CENTRAL INTELLIGENCE AGENCY
WASHINGTON, D.C. 20505

23 September 1976

MEMORANDUM FOR: The Director of Central Intelligence

FROM : William W. Wells
Deputy Director for Operations

SUBJECT : MILITARY THOUGHT (USSR): The Use of Mathematical Research Methods in Military Matters

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 examines various mathematical methods and theories which may be applied in military affairs to determine the effectiveness of weapons and other systems and form the basis for decisions. Definitions and applications are given for the probability, game and queueing theories, linear and dynamic programming, and mathematical modeling. Among problems in applying these methods, the author cites the need to employ computers to keep pace with a combat situation, and the inaccessibility of actual military data to research mathematicians. This article appeared in Issue No. 2 (69) for 1963. [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]
William W. Wells

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MILITARY THOUGHT (USSR): The Use of Mathematical Research Methods in Military Matters

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Summary:

The following report is a translation from Russian of an article which appeared in Issue No. 2 (69) for 1963 of the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal "Military Thought". The author of this article is Engineer Colonel A. Tatarchenko. This article examines various mathematical methods and theories which may be applied in military affairs to determine the effectiveness of weapons and other systems and form the basis for decisions. The "criterion of effectiveness" is explained, and definitions and applications are given for the probability, game and queueing theories, linear and dynamic programming, and mathematical modeling. Among problems in applying these methods, the author cites the need to employ computers to keep pace with a combat situation, and the inaccessibility of actual military data to research mathematicians. End of Summary

[redacted] Comment:

The author, who is a candidate of military sciences and was associated with the Institute of Applied Cybernetics of the Strategic Rocket Forces in the early 1960's, also wrote "The Use of Mathematical Methods by Staffs in the Process of Preparing the Decision for an Operation" in Issue No. 3 (88) for 1969 [redacted]

[redacted]

The Use of Mathematical Research Methods in Military Matters

by

Engineer Colonel A. Tatarchenko

The development of mathematical methods of scientific research and the ever greater proliferation of electronic computer equipment, which allows these methods to be implemented with a relatively small expenditure of time, have occasioned the growing role of mathematical research methods in military matters. In assessing this role, the starting point is the orders of the Minister of Defense and the Chief of the General Staff, which brought to the forefront the task of studying and working out questions of modern military art, especially troop control, with the use of mathematical research methods as one of the important tasks facing the military science organizations, staffs, generals and officers.

Problems solved using mathematical research methods can be reduced basically to two types.

The first type: to predict the expected result of the actions being planned. It is known that the results of any military action depend to some degree on random factors and on conditions which are unknown beforehand. For example, the dispersion of missiles is a random factor which could be assessed by calculating the probability of a hit. The meteorological conditions in the target area, which can affect the results of firing, can be included among the unknown conditions. This category also can include known factors which in the interest of simplification are not taken into consideration in the method of calculation being used. Finally, one must keep in mind that those variables which we considered changeable within certain limits, can actually go beyond these limits, and those factors which we considered unchangeable or unessential, actually can change or substantially affect our actions.

Because of all these reasons, any prediction, as a rule, makes sense only as the average of the greatest number of homogeneous actions. It is impossible, for example, to accurately predict whether an aircraft will be shot down in an isolated firing, but the average percentage of aircraft shot down in an entire series of analogous firings can be computed. In so doing, the more similar firings that have been conducted, the closer the computed average result will be to the actual average result.

The second type of problem: to select certain indices upon which the result of our actions depends, with the object of organizing them in the best way. These indices can be tied both to the tactical-technical specifications of equipment in use, and to the methods of conducting combat actions, and can define the number of participating combat elements, the sequence of actions, the forms of communications, control, subordination, and so on.

Both types of problems theoretically make it possible to obtain reliable quantitative bases for making the appropriate decisions. However, one should note that to actually find an approach to the mathematization of any tactical, operational, strategic, or general military problem is a very difficult matter requiring the intense joint work of officers with an operations background who have training in mathematics, and military mathematicians with training in operations.

After the method for solving one problem or another has been found, and the program for solving it on an electronic computer or calculating machine has been created, the practical use of the mathematical research method is considerably easier, although the joint work of the operations officers and mathematicians is still desirable. At the present level of the mathematization of military problems, when mathematical methods are used in researching only the individual elements of these problems (which are, as a rule, complex), the basic goal of the joint work of the above-mentioned categories of officers is to correctly select, at every stage of the solution of the problem, from the mathematical methods which have been prepared beforehand; to establish the most desirable sequence for the stages of the computer solution and the creative activity which gives a new direction to machine computation; to determine and feed into the computers the initial data corresponding to the methods selected; and finally, having analyzed the different variants of the solution, to recommend the best of them to the command.

In the future, in the creation of mathematical methods for solving complex as well as partial problems, the degree of automation of operational-strategic calculations may be substantially increased. Therefore, work to create a methodology for the solution of complex problems is one of the priorities at the present.

Study of the criterion of effectiveness is central to mathematical research methods. "Criterion of effectiveness" is the term for the numerical index which allows us to judge to what extent a given plan of actions satisfies the established goals (absolute effectiveness), or which makes it possible to compare the different variants of solutions among themselves (relative effectiveness).

The selection of the criterion of effectiveness is a very crucial moment in mathematical research. The criterion should be tied directly to the goal of the actions being undertaken; it should be sensitive (or, as they say, "sufficiently critical") to the change of those quantities, the value of which must be determined by the research; and finally, it should be sufficiently simple so that its physical sense would be understood and so that it could be computed conveniently, depicted graphically and analyzed.

For example, how should one select a criterion of effectiveness for the conduct of fire, in order for it to be a direct reflection of the degree of suitability of the fire for achieving a set goal?

Let us assume that a ballistic missile is being fired at a missile site. What is the goal of the firing? To hit the missile site. Therefore, the natural criterion of effectiveness is the probability of hitting the missile site.

And in general, if actions are undertaken with the object of achieving a completely specific result which can either be achieved or not be achieved (a third alternative is not given), then the natural criterion is the <u>probability of fulfilling the task</u>.

In repelling an enemy air attack, the goal of the combat actions being carried out by a grouping of surface-to-air guided missiles, is to shoot down the greatest possible number of aircraft from the number flying over the zone of the missiles. Therefore, the natural criterion of effectiveness is the mathematical expectation of the number of enemy aircraft shot down.

Thus, if the goal of the actions is to achieve the greatest possible value of some quantity (the greater, the better), then the natural criterion of effectiveness is the <u>mathematical expectation of this quantity</u>.

If the problem is to seek out a more advantageous grouping of troops in comparison with the existing one, then it is convenient to take as the criterion of effectivenss the <u>relationship of the result</u> obtained with the new grouping, to the result obtained with the existing grouping. It is convenient to use this type of criterion in examining the desirability of any changes (including changes in the weapons systems). Frequently, in problems of this type, a criterion such as the relationship of means expended to the results obtained (it might define, for example, the economic expediency of one action or decision or another) might be useful.

Combat effectiveness can be assessed graphically with a criterion such as the balance of losses of the sides. Such a criterion as the balance of forces of the sides, which usually is calculated before forthcoming combat actions, and the change of which is of interest to the command in the course of the actions, also is widely known.

During research, not one but two and sometimes even more criteria can be selected. In this instance, one of them, which satisfies the set goal to the greatest degree, is considered the main one, and the remaining are concomitant. Accordingly, one strives to improve the numerical value of the concomitant criteria only within certain limits, so that this would not have a negative effect on the value of the main criterion. For example, in repelling an enemy attack, it is desirable to take as the main criterion the mathematical expectation of the number of enemy aircraft destroyed; the minimum expenditure of surface-to-air missiles could be selected as the concomitant criterion. Obviously, one can be guided by the second criterion only within limited bounds, that is, as long as the decrease in missile expenditure will not lead to a significant reduction in the number of aircraft shot down.

Depending on the type of problem being solved and on the criterion selected, a whole series of different mathematical methods are applied during research.* The main methods are probability theory, game theory, linear programming, dynamic programming, the queueing theory, and mathematical modeling.

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* Not only mathematical, but other methods can be applied in research. For example, very simple analysis and statistics are research methods in their own right, and in addition, they are widely used in parallel with the application of mathematical methods. Thus, some coefficients and standards which serve as the initial data for calculations are determined on the basis of statistics. Very simple analysis based on a comparison of the data obtained and logical conclusions is absolutely essential in evaluating the results of the calculations.

<u>Probability theory</u> allows the numerical laws of a mass of random events to be found. In studying these events, it can be observed that the relation of the number of results in which we are interested to the number of experiments carried out (frequency of the event) is very steady as the number of experiments increases. This circumstance is utilized by probability theory.

The probability of an event is the number around which the frequency of the event in which we are interested fluctuates and toward which it tends. Probability is a sort of limit (constant) toward which the frequency of the event (variable) in which we are interested tends, when the number of experiments tends toward infinity.

For example, we are interested in a quantity such as the number of aircraft we are losing for every 100 sorties. In processing the results of the air attacks carried out under certain conditions it is possible to determine the value of such random quantities as the number of daily sorties of our aviation and the number of aircraft thereby lost per day. It also is possible to obtain for each of the days the frequency of the event in which we are interested -- the percentage of aircraft lost in relation to the number of sorties carried out. Significant differences may turn up in these figures, since on individual days the percentage of losses might be very small, and on other days it could increase sharply.

However, if one does not analyze every day individually, but adds the results together with a day-to-day running total, then one gets a different picture. The frequency of the event in which we are interested will become increasingly closer to a quite definite quantity, which can be seen especially clearly if the numbers obtained are depicted on a graph. This quantity can also be taken as the probability of aircraft losses under the given conditions.

This probability is called <u>statistical</u>, as it is obtained on the basis of statistical processing of the results of the experiment. For example, on the basis of the statistical processing of the results of the actions of aviation in the First World War, the conclusion obtained is that the probable aircraft losses at that time were 0.003 (that is, an average of three aircraft shot down for every thousand sorties). According to the experience of the Second World War, during the conduct of an offensive operation these figures fluctuated in the range of 0.01 to 0.03, depending on the type of aviation (that is, an average of from one to three aircraft lost for every hundred sorties).

There are a number of methods for obtaining the value of the probability of one event or another, not by conducting an experiment, but by means of calculations alone. In this case, the probability is called mathematical.

Statistical and mathematical probability can be used for both a well-grounded prediction of the results of future combat actions, and for comparison of the effectiveness of different variants of combat actions. Thus, if the probability of one event or another is close to zero, then it can be said of that event that it is practically impossible. If, then, the probability is close to unity, such an event can be considered practically certain.

If we know that the probability of an aircraft being shot down by one surface-to-air missile is equal to 0.7, but the probability of destroying the surface-to-air missile with the aircraft's onboard defensive armament is 0.4, then it can be said that the probability of hitting the aircraft, taking into consideration its retaliatory fire, is $0.7(1-0.4) = 0.7 \cdot 0.6 = 0.42$. Similarly, it is possible to provide a quantitative accounting not only of the effectiveness of the retaliatory fire, but also of the effectiveness of the jamming of missile guidance systems or of any of our other measures.

If the probability of an aircraft being shot down by one surface-to-air missile is equal to 0.7, then when two missiles are launched at the given aircraft, the probability increases to $1-(1-0.7)^2 = 1-0.3^2 = 1-0.09 = 0.91$. Since 0.91 is close to unity, it can be assumed that a hit on an aircraft not conducting retaliatory fire when two missiles are launched, is a certain event. If it turns out that the aircraft is able to conduct retaliatory fire against the surface-to-air missiles, then in order to destroy the aircraft, it is now necessary to launch against it, not two, but four or five missiles.

The application of the system of the probability theory, devised for a mass of events, superimposes a certain specific character on the analysis and practical use of the results obtained by using it. If, for example, we calculated the probability of hitting a small-scale target with a ballistic missile to be equal to 0.6, then this still would not allow us to make a confident judgement as to the results of one specific launch.

In a particular launch, one of two completely opposite results can be obtained: either the target will be hit with certainty or it will remain unharmed. However, if we are faced with delivering a strike with ten missiles against ten small-scale targets, then one can assume with sufficient grounds that about six targets will be hit, and about four will remain unharmed. After 100 launches have been carried out, the results will be still closer to the 60:40 proportion. The theory gives values which come closer and closer to actual practice as the number of experiments increases. This testifies to the fact that it is desirable to use the probability theory when the mass character of the conduct of one experiment or another is ensured. In the sphere of tactics, this mass character of experiments is ensured above all by the multiple repetition of the same actions by some single combat means or subunit. In the sphere of operational art and strategy, the mass character of experiments is ensured by the simultaneous participation in large-scale operations of a great number of homogeneous combat means or subunits.

Game theory allows the optimal solution to be found in conflict situations, that is, in situations in which two opposing sides are pursuing opposite interests.

Let us assume that there are three methods of action at our disposal. If the enemy were to respond to any of our methods of action in only one certain manner (that is, if he were to act according to a pattern), then, having computed the criterion of effectiveness for each of our methods of actions and having compared them, we can tell exactly which of the methods will be more advantageous for us. Thus, if the enemy structures the actions of his grouping of air defense troops in one certain way, and we can fly using three different methods, then, obviously, the best method will be the one which provides the best probability of attaining the goal.

However, it might turn out (and in reality it usually does) that the enemy will prepare several variants for repelling the attack, and we will not know exactly which variant he will use this particular time. As they say in these instances, we will not have complete and reliable information about the enemy. But on the basis of studying the enemy, we can assume that the actions of his grouping most probably will be structured according to one of a limited number of variants. Let us assume that he will most probably act according to one of three variants.

Now which method of flight should we choose? The first method is good in one case, the second in another, and the third in a third case. It would seem that the problem cannot be resolved, and everything has to be left to chance.

However, in such a situation, the game theory offers a quite definite solution. To do this, all three methods for our flight (in the game theory they are called "strategies") and the three variants of the enemy's actions are examined in turn. Our methods of action and the enemy's methods of action are entered into a table (called a matrix) horizontally and vertically, and at the places where they intersect, the corresponding values of the criterion of effectiveness are written in (in the game theory, they are called "payoffs"). By examining this table it is possible to obtain recommendations as to the method which will provide a guaranteed result, irrespective of enemy actions.

In this manner, the essence of the game theory consists in the repeated comparison in turn of the different variants of the actions of both sides with the goal of selecting the most advantageous "strategy", i.e., method of action.

In some instances, on the basis of such research, we can obtain a completely simple answer: act in accordance with one so-called "pure strategy" or another. However, in many actual situations, to obtain the most advantageous result requires that one adhere to not just one such "pure strategy" but to a so-called "compound strategy", consisting of several "pure strategies" which alternate in definite correlation. It is obvious that in this case, too, the recommendations obtained on the basis of game theory might be useful in practice, especially in researching a mass of events.

<u>Linear programming</u> allows the most advantageous solution to be found for a series of tactical, operational or other problems in which many interrelated factors are present, but actions are singular and one-sided (without taking into account the enemy's retaliatory actions and our repeated actions, that is, without taking into account the effect of losses).

For this, one of the quantities (for instance, the criterion of effectiveness) is expressed in the form of a function which is dependent on a series of variables. Then the maximum (or minimum) value of this function and the values of the variables corresponding to it are found.

For example, the method of allocating nuclear warheads among targets, the altitude and speed of flight, the composition of a group, the position of a delivery vehicle in a formation, and other important indices, can be variables. Having solved the problem, we will obtain such values for the variables, by the adherence to which we will ensure the highest effectiveness of our actions.

Since the dependent relationship among the indices is written in the form of a simple equation, this form of programming is called linear.

Dynamic programming allows the most advantageous solution to be found for a series of tactical, operational and other problems in which many interrelated factors are present and actions are multiple and two-sided (taking into account the enemy's retaliatory actions and our repeated actions, and taking into account the effect of losses on the course of the operations, that is, dynamically).

Because of this, this method makes it possible to optimally plan not only the simplest combat actions, but also prolonged, complex operations, and to work out solutions which lead to the most advantageous general final results.

Queueing theory examines the quantitative side of the processes connected with the organization of mass servicing. The term servicing, in the broad sense of the word, means the functioning of any system of servicing equipment designed to fulfil the homogeneous requirements of a mass user. To make this clear we will cite three examples of mass servicing of a military nature.

The task of the theory is to identify the basic quantitative characteristics of the mass servicing process which allow the quality of its organization to be assessed. Having such characteristics at our disposal, we can find the weak point in the organization and improve it.

As can be seen from the table, "an input flow of requirements" is entering the servicing system, and an "output flow" is leaving. In those instances when a requirement can afford to wait for servicing to begin (for example, a defective aircraft which has arrived at a repair workshop), the output flow will consist entirely of requirements which have been serviced (repaired aircraft), but in this instance, a line of aircraft awaiting repair accumulates. In other instances, the requirement cannot wait for servicing to begin (for example, if enemy aircraft are flying into the depth of our defense), and if the throughput capacity of the servicing system (group of surface-to-air guided missile systems) is insufficient, then the output flow will consist of both serviced requirements (aircraft shot down), and unserviced requirements (aircraft which have penetrated).

As a rule, in the majority of military mass servicing tasks, the input flow depends not on our will, but on a whole series of random factors, among which, to be specific, the enemy's will also can be included. Therefore, to determine the number of requirements entering in a given period of time, one resorts to the probability characteristics of the input flow (for example, the average density of the flow of aircraft in an attack).

The time it takes to service one requirement with one servicing unit in a general case also is a random value. In actual fact, each of the aircraft entering the repair network, depending on the nature of the damage, will require the expenditure of various amounts of labor for the repairs; the firing cycle of a surface-to-air guided missile system may also vary depending on the nature, altitude, speed, and parameter of the air target. Therefore, for every mass servicing process, there has to be found a law for the allocation of servicing time, i.e., that function which would determine for every period of time the probability that within that period of time the servicing would be finished (in solving practical problems, the average servicing time, for example, the average time expended in firing upon one aircraft, often is used).

Whereas the input flow of requirements and the servicing time of one requirement frequently do not depend on us, then it is our competence which is entirely responsible for the manner in which our servicing system functions. What does it mean to have well-organized functioning of a servicing system? This means the achievement of a state in which a long line of requirements does not form, requirements are not left unserviced, and in which the servicing equipment is not idle. For this, it is above all necessary to apportion an appropriate amount of servicing equipment (for example, to correctly determine the required detail of surface-to-air missile forces). Further, the servicing equipment should be grouped properly and the entering requirements should be allocated among the servicing equipment in the most desirable way (i.e., the most rational target allocation should be implemented in repelling an attack).

The importance of the queueing theory is based on the fact that it enables the quantitative indices of the quality of servicing to be given and to be expressed through quantities which define the input flow and servicing time.

In the military field, the queueing theory may find the greatest application in solving the following problems:

-- the problems connected with the setting up of all kinds of military servicing systems, with the object of constructing the optimal system in each specific instance; here we are concerned primarily with evaluating the quality of defense systems, as well as repair, supply, and medical-sanitary systems;

-- the problems connected with setting up the control of forces in battle; here we are concerned primarily with evaluating the quality of the systems for transmitting and processing information about a situation, which is especially important when setting up automated control systems;

-- the problems connected with the use of queueing theory methods when producing models of the processes of combat actions.

For example, in setting up an air defense (or missile defense), the process of firing upon bombers (missiles) can be considered a mass servicing process, and the reception of target data (blips) on radar screens can be considered the entry of requirements for servicing. In this case, using the methods of the queueing theory, it is possible to compute a criterion of effectiveness such as, for example, the percentage of bombers (missiles) which are not hit when the defense is set up this way. The queueing theory will help find a way to set up the defensive system so that, for a given quality of individual antiaircraft installations and set quantity of them, the greatest protection of the airspace or installation would be afforded.

Modeling of military actions. In the past few years, we have resorted more and more to the mathematical modeling method to calculate all the essential connections among events, and to find the laws governing complex bilateral processes which consist of a series of consecutive, parallel, and alternating simpler processes.

The point is that the methods described above and other mathematical methods still do not allow an analytical or graphic solution to be found for the whole series of complex processes that military actions can be.

Mathematical modeling of combat actions to obtain characteristics of interest to us, became possible only with the appearance of electronic computers, which make it possible to play out these actions a large number of times within a comparatively short time and with a small expenditure of means.

It was not mathematical, but game and physical modeling which were widely applied before and continue to be applied now. Thus, any military command or staff game in which two opposing sides and a directing body are participating, can be considered game modeling. The directing body issues to the sides certain information about the situation they are analyzing. As a result of the analysis of the information and on the basis of their own experience, knowledge and very simple calculations, the sides reach decisions which, in their opinion, are the most appropriate for the situation which has taken shape. The directing body, by comparing the decisions, determines the result of the actions of the sides and reports it to the players in the form of new information (introduced according to the situation). This process is repeated again and again, making it possible, after the results of the game have been summarized, for an approach to be found to the solution of extremely complex problems which are still impossible to deal with using other methods. However, to identify the governing laws, and to ascertain the most stable relationships among various events, it is necessary to make as many moves as possible in the game, and this is not always possible, since it leads to prolonging the game.

An example of the physical modeling of the processes of combat actions are the various troop exercises with combat equipment in the field. Depending on the tasks assigned for the exercises, the forces and means allocated, as well as the time of year and day and the method by which they are conducted, the exercises, as a model, approximate actual combat actions to one degree or another, but of course they are never completely analogous to them. It is sufficient to say that, as a rule, the forces of the sides do not diminish, that is, losses which in future combat actions might reach enormous proportions are not taken into account. In spite of this, the exercises are a powerful means of identifying the most stable relationships and laws for working out the basic principles of military art, and for the training of personnel in the control of troops and combat equipment.

In contrast to these forms of modeling, a mathematical model represents combat actions by means of a certain mathematical abstraction of processes which take place in actual practice.

Mathematical models can be divided into analytical models, and models based on statistical analysis (the Monte Carlo method). The essence of the analytical model consists in the fact that the parameters which determine the development of combat actions are related to time by a certain system of equations. The essence of the model based on the Monte Carlo method consists in the fact that a formalized flowchart of the operation being studied is repeatedly read on an electronic computer according to a special algorithm. In the process, various random deviations of the parameters are taken into consideration by means of random numbers, using the necessary law of distribution.

The model is programmed for a specified type of electronic computer (or computer system). All necessary constant initial data are fed into the computer's memory, after which the playing out of a model can begin.

By modifying the variable initial data in a certain sequence or by the use of random-number generators, the result of each playing out is obtained. The results obtained are processed and analyzed, as a result of which the relationships and laws inherent in the model are identified. The degree to which the data obtained approximate the actual results depends on how skilfully the model was constructed. The optimal solution obtained by using the model can subsequently be implemented.

The model of combat actions, the model of an operation (particularly under peacetime conditions) might turn out to be the only way of providing us live contemplation of one event or another. At the same time, it frequently is the only method for practical testing of the results of our abstract thinking.

Besides research purposes, the application of models is of great interest in troop control, as well as in the training process. For the effective application of mathematical modeling in support of troop control, while preparing for and during combat actions it is essential to resolutely shorten the time needed to prepare the necessary variable information and feed it into the computer. For this purpose, the combined use of general-purpose and information-logic computers is promising. Accordingly, new data on a situation should continuously be sent automatically to the information-logic computer, be continuously processed in it, and enter the general-purpose computer which solves one problem or another. The results of the solution must be output from the computer not only on the printer unit, but also on the visual display unit, so the command can use these results for troop control without delay.

The use of modeling for training purposes will make it possible to use an electronic computer for a certain number of hours to analyze complex operations which now take the trainees a long time to play out.

* * *

V. I. Lenin said: "In order to really know a subject, one must comprehend it, study all of its aspects, connections, and 'instrumentalities'. We will never fully achieve this, but the demand for thoroughness will caution us against mistakes and apathy." (Collected Works, Vol. 32, p. 72)

Through the application of mathematical research methods, we also are not able to fully comprehend all aspects and relationships of an event, since we are far from being able to express them all mathematically. Therefore, the conclusions obtained through such research are still not a solution in the full sense of the word, but only a basis for making a decision, which is the result of the staffs' intense creative activity and the commander's act of will.

However, the fact that the command receives the kind of data to think over, which previously, before the application of mathematical research methods, was inaccessible to it, will serve as a powerful stimulus for an ever greater scope and depth to the creative activity of the commanders and staffs.

Just as the command, under present conditions, needs the supplementary data obtained by mathematical research methods in working out a decision, so do the conclusions of the research need the supplementary factors introduced by the command in order for the conclusions to fully mature into a decision.

In addition, the commander's will is displayed in the selection of the main quantitative criterion of effectiveness. And finally, the commander's will, based on the responsibility vested in him, has to give an executive command for actions in accordance with the decision.

From the very simple examples of the application of mathematical research methods cited in this article, it follows that the process of finding the optimal indices of actions being planned requires protracted calculations and prolonged experimentation. In addition, in present-day operations, the time factor is frequently crucial. Therefore, it is understood that the wide practical implementation of mathematical research methods is directly linked with the employment of high-speed computer equipment in the troops.

But, at the same time, we must not think that the lack of electronic computers or the inability for some reason to use them in a combat situation does not permit the use of mathematical research methods at all. In a number of instances, on the basis of the usual methods for studying a situation and certain very simple calculations, the essential conclusions can be made concerning possible improvements in the organization of combat activity, whereas detailed and complete research by use of electronic computers yields only a small additional result. Therefore, under combat conditions we should never scorn rough calculations; we must study them and master the method for performing them manually, supporting them with tables, graphs, and nomograms calculated beforehand, including those drawn up with the use of computers.

In conclusion, we would like to dwell on the following question.

At present we find ourselves at that stage in which the main efforts of military mathematicians are concentrated on working out methods for solving specific problems. Various military science organizations are working to produce algorithms and programs for certain specific questions applicable to the specific requirements of the branch of the armed forces or branch arm they are servicing. This stage can be compared with the stage of the procurement of parts for the construction of a building, and is completely natural. It is assumed that this inductive method makes it possible to build a well-proportioned and finished structure.

And this will in fact occur if there is an overall plan for building such a structure, and if each organization manufactures a certain part in accordance with the overall plan. However, at present various organizations are making the very same parts in various ways, at times duplicating each other, while a great number of parts which are very important to the construction are not being produced at all.

At present mathematicians frequently work to increase our military strength not directly, but indirectly, developing one method or another based on arbitrary initial data, for they have access to neither true initial data, nor the existing plans for actions. Therefore, a considerable degree of abstractness is still characteristic of mathematical research. The recommendations which are being worked out cannot without revision be applied to a single specific operation by our armed forces against specific enemy forces in a specific theater, and at times they assume the nature of truisms which have long been known to military figures. The methods themselves sometimes require initial data about the enemy which is impossible to obtain within acceptable time limits.

To obtain the proper effect from mathematical research methods, we must at all costs find those organizational forms whereby researchers and staffs could work together on specific plans for armed combat.

We fully understand that there is a large amount of data that cannot be released by the General Staff (and other staffs) under any conditions; consequently, one course of action remains -- to bring research mathematicians into the General Staff (and other staffs).

The possibility of finding other ways of resolving this question has not been excluded, but it is perfectly obvious that military science and military art can obtain from mathematical research methods significantly better results, useful for practical purposes, than those which are being attained today.

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TABLE

Servicing system	Servicing equipment making up a given system	What servicing consists of	Input flow of requirements for servicing	Output flow of serviced requirements
Aviation repair network of an air army	Aviation repair workshops (or repair groups, brigades)	Repair of aviation equipment	Aircraft, engines and other aviation equipment to be repaired	Repaired aviation equipment
Group of surface-to-air guided missile systems	Surface-to-air missile systems (or individual launchers)	Destruction of enemy aircraft and cruise missiles	Enemy aircraft and cruise missiles detected by radar and flying through SAM zone	Enemy aircraft and cruise missiles shot down
Personnel decontamination treatment system	Decontamination treatment-cleansing stations	Personnel decontamination treatment	Personnel requiring decontamination treatment	Personnel who have undergone decontamination treatment

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