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Mathematical modeling of combat operations in military history research

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ANNOTATION
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Relevance of the research topic. The experience of local wars and armed conflicts of recent decades shows that modern combat operations and operations (hereinafter referred to as combat operations) will be distinguished by exceptional complexity, large spatial scope and an increase in the scale of the impact of combat systems. This is mainly due to the shift in the center of gravity of the armed struggle to the aerospace and information spheres. Under these conditions, the choice of a rational method of conducting them acquires great importance in the course of planning military operations. At the same time, the most important conditions for successfully achieving the goals of modern military operations are timely tracking and displaying in near real time the situation in conflict zones, forecasting its development, and working out various options for the actions of the troops of the parties.

One of the ways to solve this problem is the simulation of hostilities. At the same time, mathematical modeling is the most promising. It does not require large material outlays, it ensures the prediction of the results of hostilities in various scenarios of their development, as a result of which the validity of the decisions made is increased. In the practice of military affairs, mathematical modeling can be used in many areas: in the study of hostilities, predicting the results of hostilities, planning and conducting combat operations, planning the comprehensive support of military operations of troops, as well as in solving any problems associated with the cost of time, material, energy , financial and other resources. Correct model building ensures the success of planning and is one of the most difficult modeling tasks.

The First President of the Republic of Kazakhstan – Leader of the Nation Nursultan Nazarbayev, speaking on May 19, 2021 at a meeting of the Security Council of the Republic of Kazakhstan, pointing out the importance of automating the management of military processes, noted: «The military confrontation of states will be tested by the level of technological support. In the near future, the theater of military operations will begin to take shape in the digital environment. The wars of recent years, if we take what we saw in Syria, Nagorno-Karabakh and so on, showed the colossal role of satellite surveillance, communications and navigation. The so-called army of the future will be determined by the automation and control of military processes and the introduction of new technologies».

At present, mathematical modeling is one of the main methodological achievements of the scientific and technological revolution, which makes it possible to reduce costs by dozens of times and increase the efficiency of operational training and military scientific research. The development of simulation, computerization in the leading armies is seen as an important means of preparing for war and military rivalry. In modern conditions, the effectiveness of weapon control is determined by the quality of models of movement and object recognition, while the effectiveness of command and control of troops is determined by the quality of models of the dynamics of combat actions and operations. As an objective tool for analysis and optimization, mathematical modeling makes it possible to analyze in detail the essence of the processes of armed struggle, to reveal its quantitative patterns and, consequently, to find optimal solutions and options for combat operations.

The relevance of the research topic is also due to the need for a more thorough study of the experience of armed struggle, generalization of the experience of hostilities and battles. Scientific and technological progress in various fields, from the emergence of new models of weapons and military equipment to information and communication technologies, has led to a qualitative change in the nature of armed struggle. The emergence of new forms and methods of armed struggle urgently requires the search for new methods of study, generalization and their implementation in the practice of training troops, incl. using computers and mathematical modeling.

The most topical issues are the simulation of combat operations in military-historical research. The practical application of the simulation of combat operations using examples from the history of wars will make it possible to more deeply reveal and understand the patterns of armed struggle. A posteriori verification of the model of combat operations on these examples also serves as a criterion for the adequacy of models of combat operations and their use in forecasting and planning combat operations. The use of mathematical modeling of armed struggle makes it possible to reveal the quantitative measure of the studied historical processes and phenomena, to give a more accurate and rigorous expression of the corresponding qualities.

The development of the «microcomputer revolution», the spread of a new generation of computers with a huge. memory, high speed and branched software, as well as the development of a number of new methods of applied mathematics and operations research, have opened up opportunities for military historians to set and solve new research problems, which include the process of building various particular models of processes studied in the subject area under study.

Based on the foregoing, relevant at this stage are the tasks of both generalizing the accumulated experience and creating new methods for processing and analyzing data from historical sources, modeling armed struggle using examples of past wars that meet the new needs of the development of military history and new possibilities of applied mathematics and informatics.

In this regard, there is a need to generalize the experience of using mathematical modeling in military-historical research, to determine the main directions and areas of their application in the study of wars and armed conflicts of the historical past.

An analysis of publications and scientific papers based on the simulation of hostilities will deepen the understanding of the scientific method as a set of ways and principles, requirements and norms, rules and procedures, tools and tools, that is, methods that ensure the interaction of a scientist-subject with a cognizable object to solve a research problem.

Thus, the relevance of studying the mathematical modeling of combat actions follows from the logic of the importance of studying new forms and methods of armed struggle in the context of globalization and the scientific and technological revolution, as well as from the objectivity of the process of enriching and expanding the arsenal of historical research methods based on computer and information technologies.

The disclosure of this topic based on the generalization and analysis of the experience and practice of using mathematical modeling of military operations in

historical research, as well as the proposed theoretical conclusions of the study and the possibility of their use in military historical research, testify to the relevance and significance of the proposed dissertation work.

The degree of knowledge of the problem. The development of military affairs is mostly based on the analysis of the experience of past wars, however, in modern conditions, computational experiments using various types and scales of mathematical models and modeling complexes, with which you can predict the nature of future armed clashes, test new weapons, new technologies for organizing and conducting military operations.

The analysis of these problems requires preliminary consideration of more general aspects related to the use of mathematical modeling in historical research. A large number of works are devoted to the methodological problems of applying mathematical methods and models in historical research. These problems are most thoroughly considered in the monograph of a specialist in the field of the methodology of history, academician I. D. Kovalchenko.

Meanwhile, the theoretical and methodological problems of modeling combat operations in military-historical research have not yet been properly developed. And it is necessary for a correct understanding of the essence of this method, the principles and ways of constructing models of combat operations and their meaningful interpretation.

In foreign studies, the pioneer of the mathematical description of the battle is mainly indicated by the Englishman F. W. Lanchester. Beginning September 4, 1914, Lanchester published a series of sixteen weekly articles in Engineering magazine. The fifth and sixth articles, published on October 2 and 9, were devoted to the mathematical description of hostilities. After the First World War, intensive research on this subject was carried out in several military research institutes. A wealth of data from World War II and earlier wars has been collected and analyzed to test and develop the theory of warfare simulation. Mention should be made of the contribution of J. H. Engel and H. C. Weiss. This painstaking work almost stopped for a while, but resumed in the 80s and 90s of the XX century. In this context, the work of T. N. Dupuis and D. S. Hartley can be mentioned.

In the Soviet Union, the works of Yu. V. Chuev, F. I. Ereshko, V. Gavrilov, V. F. Krapivin, P. N. Tkachenko, V. N. Zhukov should be mentioned.

The general problems of modeling combat operations in historical research have not received extensive coverage in historiography. Only a few works can be noted here. In this direction, there is a wide range of problems, the solution of which is important for the practical modeling of combat operations in military historical research.

The study and analysis of both scientific works of domestic and foreign authors on the problem under study, and studies where mathematical modeling of military operations was used, allow us to draw the following conclusions. Scientific works devoted to the historical analysis of mathematical modeling of combat operations are not of a generalizing nature and are mainly reduced to listing scientific works and research in this area. The historical analysis of the application of mathematical

modeling of combat operations, as a specific area of theoretical and practical activity, has not yet been sufficiently studied.

Thus, further comprehensive study of the mathematical modeling of combat operations will only contribute to the effective use of mathematical modeling of combat operations in military historical research.

In connection with the designated problem, we have chosen the topic of the dissertation research.

The purpose of the study is to summarize the accumulated experience, to identify the features and prospects for their application, based on the analysis of military-historical research on mathematical modeling of combat operations.

Research objectives:

- to substantiate the main periods of development of the use of simulation of combat operations in military historical research;

– to streamline and systematize the directions of modeling military operations in historical research,

- to study the features and development of approaches in the development of mathematical models of combat operations;

– to propose a methodology for the application of mathematical modeling of military operations in the research work of a military historian.

The object of the study is a complex of scientific works and studies that reflect the theoretical and applied aspects of modeling combat operations in military historical research.

The subject of the study is the experience and practice of using mathematical modeling of combat operations in military history research.

Research methods. Fundamental for the dissertation research are systematic and interdisciplinary approaches. The first of these involves, in our case, an interconnected study of individual works of various researchers, the identification of their points of view on various issues, concepts and opinions, and their appropriate assessment. At the same time, work on modeling military operations is considered in the context of general historiography. The second approach - interdisciplinary - follows from the interdisciplinary essence of the analyzed works themselves, which were created at the intersection of at least two sciences: military history and mathematics.

The work is based on the principles of historiographical analysis, which implies, in interconnection, the disclosure of the methodological attitudes of researchers, the source base they use.

In addition to general scientific ones (analysis, synthesis, description, etc.), we used special methods of historical research, such as historical-comparative, historical-descriptive, historical-typological. The problem-chronological method allowed us to consider the works, based on the problems that they reflect, to trace the process of developing a particular problem. For this work, it is important to classify the literature according to the most important aspects and directions.

The chronological framework of the study covers the period from the beginning of the twentieth century to the present. The lower limit is due to the formation of prerequisites and conditions and the actual appearance of the first

scientific works devoted to the mathematical modeling of armed confrontation. The upper limit is determined by the fact that the use of mathematical modeling of combat operations in research is growing exponentially, a number of researchers still consider them an indispensable tool in their work.

Scientific novelty is as follows

– for the first time, based on a systematic analysis of sources, military and historical literature on the modeling of hostilities, periodization was carried out;

– for the first time, a typology of mathematical models of combat operations was compiled, taking into account the chronological development of approaches to modeling;

- a mathematical model and interpretation of the Orbulak battle was compiled;

- a mathematical model of a hybrid war was compiled using system dynamics methods.

Describing the novelty of the work in concrete historical terms, we note the following.

There are very few works in historiography that would generalize the already existing achievements in the field of mathematical modeling of combat operations, especially this concerns foreign experience in modeling combat operations. This work is the first comprehensive scientific analysis of the accumulated experience in mathematical modeling of combat operations from the time they began to be used until today. Analysis of the application of mathematical modeling of combat operations in military history research, the study of foreign studies and projects allows us to identify trends and patterns of development, the most promising, popular areas for the use of mathematical modeling of combat operations in military historical research of military science in Kazakhstan.

Provisions for defense:

1. The formation and development of the theory of mathematical modeling of combat operations is associated with the needs of military science in a constructive analysis of various aspects of military activity, as well as the need for the professional military historical community to expand the research tools of military historical science in the context of large-scale changes in the field of computing technologies and the formation of a new computer environment for scientific research.

2 During the work of researchers using mathematical modeling of combat operations, the most attractive areas in terms of their application have been formed. The developed mathematical models of combat operations have features determined by the levels of resolution and aggregation, which are complex from the point of view of sources that are different in structure, content and origin. With the growth of computational capabilities, mathematical models of combat operations are rapidly expanding in size, volume and complexity. This expansion of the models makes them more detailed, allows you to operate in larger units and over longer periods of time. Improved combat models allow you to more accurately study and determine the factors that historically determined the outcome of hostilities.

3. In the structure of the theory of mathematical modeling of combat actions, three main approaches can be distinguished: differential equations, a simulation

campaign and an estimate of the magnitude of firepower, which developed in parallel, but by no means synchronously. At different stages of development, these components show similar dynamics, or a change in research priorities brings one or another of them to the fore.

4. The use of mathematical modeling of combat actions in historical research will make it possible to study and understand in more detail the patterns of armed struggle, the advantage of which is to reveal the quantitative measures of the processes and phenomena being studied. The developed models of combat actions can be used in modeling alternatives of the historical process and for prognostic purposes. The widespread use of mathematical models of combat operations allows historians to assess the plausibility of competing hypotheses, to revise or re-evaluate hypotheses formulated decades ago and are still the subject of debate due to the lack of an adequate quantitative basis. Mathematical modeling tools allow you to create a dynamic map of combat operations with the possibility of its adjustment at any stage of the study. The use of mathematical modeling of combat operations implies the interdisciplinary interaction of researchers, primarily military, historians, mathematicians and computer technology specialists.

Theoretical and practical significance of the research.

The theoretical value of the work lies in the fact that the provisions and results of the dissertation can be used in the course of scientific research on the problems of military history, which increases the efficiency of studying the patterns and relationships between the history of war, the army and the development of military art. The materials and scientific results of the study can be used when writing separate sections in generalizing works on the academic disciplines "Theory and Methodology of Military Science", "Operational Art" of textbooks on military history for military educational institutions.

The materials obtained during the study can be used to write summarizing works in the field of mathematical modeling of combat operations in historical research, to create training courses in the field of historiography, methodology and methods of historical research, and can also be used as the basis for similar studies. Recommendations on mathematical modeling are intended to assist historians-researchers-doctoral students.

Research sources. The sources for this study were scientific articles and monographs of scientists, which are fundamental in the field of mathematical modeling of military operations and cover for the most part the main range of areas of application of mathematical modeling of combat operations in military historical research. Since the work examines the accumulated practical experience, identifies problems and topical issues in the field of the topic under study, we can talk about historiographic sources, "which are determined by the subject of historiography and carry information about the processes taking place in historical science and in the conditions of its functioning."

Most of the sources in this study consist of articles, reports, and dissertations prepared in the United States. Many of them come from military research institutions such as the Naval High School in Monterey, California, and the Institute for Defense Analysis in Arlington, Virginia. In Europe, much valuable work has been done in

the United Kingdom at the Office of Defense Operational Analysis and at the Royal Military College; in Italy at the Research Center SACLANT ASW; in the Netherlands at the SHAPE Technical Centre; in Germany at the IABG in Munich; in Sweden at the Defense Research Agency; and in Switzerland at various institutes and research departments of the military department.

The analysis also involves the materials of journals in which military scientific articles are published: "Military Thought", "Foreign Military Review", other university and academic journals, industry journals on mathematical modeling, thematic collections of articles, monographs and educational and methodical publications.

However, the issue of publication confidentiality is a problem in this area of research, since most of the research is carried out in the interests of the defense departments. Some countries are less liberal in their attitude than others, and not all scientific works in this area can be examined. The trend is to allow the publication of theoretical papers and classify only those studies that include mention of specific equipment or parameter values that may be of national security importance. However, another recent trend has been to release the document, but with the author and all references removed. This makes it very difficult to use the material in research, but does not prevent the information from being applied elsewhere.

Approbation of the dissertation. The main content of the dissertation work, its theoretical provisions, conclusions and recommendations are reflected in 14 scientific articles, 9 of which are published in publications recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 4 in the materials of international conferences and 2 in a closed edition, also in 2 acts of the results of scientific research during the command and staff exercises «Bilimmen zheniske – 2019» from March 16 to 18, 2020, command and staff war games «Bilimmen zheniske – 2020» from March 26 to 28, 2020 Received 2 certificates of entering information into the state register of rights to objects protected by copyright.

Brief description of the dissertation structure. The dissertation work consists of an introduction, three sections, a conclusion, a list of references and two appendices.

The following scientific results were obtained in the dissertation work.

The first scientific result - on the basis of the analysis of scientific literature, revealing aspects of the application of mathematical modeling of combat operations, the accumulated experience is summarized and the periods of development of the use of mathematical modeling of combat operations in military-historical research are substantiated.

The development of mathematical modeling of combat operations can be characterized as a whole as a progressive movement that has avoided extremes. It was due to an objective assessment of the role and place of mathematical modeling of combat operations in historical research. Mathematical modeling of combat operations as a research method has its own limits of application and must be combined with other traditional methods. The success of the application of these methods depends on the theoretical and methodological ideas and principles on the

basis of which the research task is set, the selection, processing and analysis of data from a historical source is carried out.

The formation and development of mathematical modeling of combat operations as a method of military historical research took place in several periods. The beginning of comprehension of the possibilities of mathematical formalization of military operations for improving the research methodology was associated with the first experiments in the application of quantitative and mathematical methods to study the phenomenon of "war". This was the period of formation of the theory of mathematical modeling of combat operations. However, these studies remained scattered until they were picked up by the general stream of scientific developments, the beginning of which is only associated with the 2nd period.

The second period in the development of the theory of combat operations modeling and the application of mathematical methods of analysis is associated with the outbreak of World War II (hereinafter referred to as WWII) and includes the mobilization of scientists in the interests of military science, as well as the development of new types of weapons and their continuous improvement, the study of the human factor involved in their use, and a constant search for better methods of their application. During this period, mathematical methods of analysis, incl. mathematical modeling of combat operations, defense departments in many states show practical interest. Laboratories and research institutes that work within the framework of defense orders are beginning to be created. This contributed to new research in the field of mathematical modeling of combat operations.

The formation of the theory of modeling combat operations during WWII took place within the framework of the theory of "operations research" and various theories of military science: the theory of combat effectiveness, the theory of combat positions and combat spaces, the theory of combat potential, the theory of fire damage, the theory of search, etc.

The intensive growth in the number of publications during WWII and the post-war years contributed to the accumulation of a large number of scientific results. But the use of mathematical modeling directly in the process of operational planning at an early stage was very difficult and required considerable time for calculations. This was important both from the point of view of their use in mathematical calculations leading to elegant final formulas, and from the point of view of the availability of calculations using tables and slide rules, which were typical for the 40s-50s. Manual calculations and the use of maps or tables were useful, but cumbersome and slow, limiting the ability to create complex models. Naturally, improved computational capabilities could change this, and did so, allowing simpler, more abstract models to be computed quickly and the more complete and complex models needed to understand the increasingly complex and global nature of warfare to be developed.

The third period in the development of mathematical modeling of combat operations is associated with the advent and development of computer technology, which made it possible to approach the solution of qualitatively new research problems in those areas in which direct experiment and the search for laws empirically are seriously hampered. Combat simulation as a discipline has itself evolved at a rapid pace, and the effects of this rapid evolution have been seen in

several important areas. Research carried out in the interests of the army has expanded "from narrow specific projects of a hardware nature to broad theoretical problems, involving full segments of military operations."

Progress in the development of new information and computing technologies not only creates a technical basis for the effective use of mathematical modeling of combat operations in military history research, but also expands the scope of these methods themselves, creating more flexible structures for formalizing military history knowledge. Whether used as an analytical tool to support critical defense decisions or as a historian's research tool, simulation remains a technology in demand.

Thus, the formation and development of the theory of mathematical modeling of combat operations is connected with the needs of military science in a constructive analysis of various aspects of military activity, as well as the need for the professional military history community to expand the research tools of military history in the context of large-scale changes in the field of computing technologies and the formation new computer environment for scientific research.

The second scientific result - The existing typologies of models of combat operations are analyzed with an analysis of the possibilities of application in military-historical research. A classification is proposed that takes into account the structure of mathematical models of combat operations. Significant differences in the structure of the model relate to how the model handles time and probability, the level of aggregation, the scale, the processes represented, and the combat aspects considered.

There is a wide range of possible types of mathematical models that can provide a theoretical basis for combat modeling. Underlying each of these types of models is a set of specific assumptions, constraints, and capabilities.

A model rarely includes all the components and interactions of a real system; if that were the case, it would be just as easy to study the original system. In many cases, all processes and interactions of the system are unknown or not understood, especially if they involve people or elements of chance. The "minor" aspects of the system are eliminated, while the "important" aspects are invariably abstracted and simplified. Whether a model is a faithful representation of a real system depends on both the intended use of the model and the structure of the model itself.

The existing classifications of models of combat actions do not give a complete picture of the methods of constructing models, the structure of such models, and the completeness of their consideration of various “kinds” and “types” of uncertainties that have a dominant influence on the course and outcome of simulated military operations. The proposed classification of combat operations models takes into account the structure of the models. Combat patterns may include a number of distinctive features that the classification scheme regards as exclusive or contrary. Significant differences in the structure of the model relate to how the model handles time and probability, the level of aggregation, scale, processes represented, and aspects of the combat environment considered.

Historically, three main approaches have been used in models to determine the outcomes of combat operations, along which combat simulation is progressing,

noting further that all three eventually merge to some extent into the simulation of large-scale armed conflict:

a) Differential equations;

b) Simulation approach;

c) Estimation of the magnitude of firepower.

Differential equations are critical to understanding the development of mathematical combat models. Modified Lanchester equations form the basis of depletion functions in modern combat simulation models. Developers use these models for force calculation, force verification, and combat training.

With the development of high-speed computers, Monte Carlo duels have expanded into models of more complex ground combat operations involving an ever-increasing number of units up to an organizational level roughly the size of a battalion. As a rule, models, initially less detailed, moved towards more and more "realism" and higher resolution. Along with the attrition modeling enhancement provided by the Monte Carlo simulation, it became possible to model many other important combat functions and variables such as weapons and sensor combinations, movement, terrain, communications, doctrine, intelligence, etc.

Both deterministic and stochastic models and scoring models are useful methodologies that can be built into larger simulations to solve the specific problems they are designed for, such as exhaustion and strategy selection. It is in this built-in use that we see the true utility of these modeling approaches.

Models of combat operations reflect about the same number of approaches as there are models to the problem of taking into account indirect elements and combat processes. These elements and processes are major factors in determining the outcome of a battle, but there is little understanding of the relative importance of each. Moreover, there is very real uncertainty about the validity of much of the combat models developed. Conducting verification and validation is one of the most difficult aspects of combat simulation. The key problem underlying many other problems, in our opinion, is the lack of connection between existing combat models and reality, i.e. the problem of combat model validation. This issue is not expected to change as each new simulation study is unique and makes verification and verification difficult.

Thus, mathematical models of combat operations become a relevant quantitative tool for historical research. The widespread use of mathematical models of combat operations allows historians to assess the plausibility of competing hypotheses, to revise or re-evaluate hypotheses formulated decades ago and are still the subject of debate due to the lack of an adequate quantitative basis. Such an initiative can transform the discipline if it solves the problems associated with the study of the dynamics of wars and armed conflicts. These difficulties are based on the complexities of modeling social interaction and the methodological problems that arise when evaluating mathematical models compared to data with a low sample size, high variance, and strong fragmentation.

The third scientific result is a method for applying mathematical models of combat operations in military-historical research.

The general preference for using mathematical warfare models to provide quantitative information in military history research is due to the convenience and accessibility that such models provide, as well as the reproducibility of the outputs or results that are achieved with any given set of inputs.

However, the key problem underlying many other problems, in our opinion, is the lack of connection between combat simulation models and reality, i.e. combat model validation problem.

Although warfare is complex and does not follow deterministic rules, the proposed research methodology provides many tools for reducing complexity and managing uncertainty in support of military decision makers and will enable better decisions for both commanders and on the battlefield. Improved conflict models based on a better understanding of the factors that have historically determined conflict outcomes should lead to better solutions and better outcomes.

The proposed ambush combat model can be seen as a further generalization of Lanchester's models, covering all three alternative specifications: aimed fire, unaimed fire, and asymmetric model. The main characteristics of the ambush combat model are as follows. First, the topographic constraint makes the quality and size of the constraint more significant factors in the outcome of a battle, reducing the relative importance of quantity. In particular, restrictions on chokepoints and the direction of fire favor the defending side by eliminating the numerical advantage of the attackers. Secondly, the asymmetric nature of the battle reduces the combat effectiveness of the attacking side.

Modeling hybrid conflict as a tool for cognitive activity can be particularly useful. Military authorities need simulation tools to refine and test various ideas on how to contain and counter a hybrid threat. Mathematical modeling of a hybrid conflict will make it possible to better understand the phenomenon of a hybrid conflict, to recognize its goals, potential phases of the conflict, actions and decisions of the enemy. The results obtained can help in predicting the development of hybrid conflicts, stopping the «hybrid war» at its earliest stage and preventing its transition to the phase of a full-scale military conflict.

Armed forces around the world face the uncertainty of a rising threat and intensifying fighting, as well as the responsibility to anticipate the nature of conflict in the coming years. They must continue to develop and integrate advanced technologies to guide, equip and train forces to meet these challenges. Combat simulation is an effective tool in tackling these challenges, and the field is growing rapidly as militaries around the world seek to develop and deploy the tools of the future. Whether used as an analytical tool to support critical defense decisions or as a historian's research tool, mathematical warfare modeling remains a technology in demand."