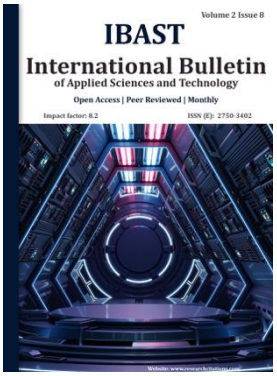

ON THE HISTORY OF THE DEVELOPMENT OF MILITARY MODELING

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Abstract: This article examines the main stages in the emergence and development of military modeling from ancient times to the beginning of the twentieth century. It analyzes the approaches to military modeling employed by outstanding military commanders, investigates the features of the first professional military conflict simulation system, *Kriegsspiel*, and considers the contribution of twentieth-century military scholars to the development of the theory of military modeling.

Keywords: military science, modeling, planning, simulation, force ratio, analysis, enemy disposition, scenario, commander training, terrain.

Аннотация: В статье рассмотрены основные этапы становления и развития моделирования боевых действий от древнейших времён до начала XX века. Проанализированы подходы к моделированию, применявшиеся выдающимися полководцами, исследованы особенности первой профессиональной системы имитационного моделирования вооружённого конфликта «Kriegsspiel» и рассмотрен вклад военных учёных XX века в развитие теории военного моделирования.

Ключевые слова: военная наука, моделирование, планирование, имитация, соотношение сил, анализ, расположение противника, сценарий, подготовка командиров, рельеф.

In modern military science, modeling has evolved from an auxiliary tool into a fundamental component of strategic planning and operational preparation. Today, digital battlefield models, combat simulation systems, and artificial intelligence-based analytical algorithms make it possible to evaluate tens of thousands of potential conflict scenarios while taking into account weather conditions, terrain, the electromagnetic environment, and the psychological state of military personnel. This enables military commanders not only to anticipate possible courses of combat operations but also to optimize logistics, resource allocation, and decision-making timelines, thereby improving the effectiveness of military planning and significantly reducing the risk of errors before the onset of combat operations.

However, the concept of «playing out» combat operations on maps or models did not originate in the era of supercomputers; it evolved alongside the development of military art. In earlier periods, military modeling took physical or mental forms, including wooden terrain models (used, for example, by Alexander the Great and Alexander Suvorov), sand-table models, and detailed staff war games conducted on maps by Prussian military officers during the eighteenth and nineteenth centuries. Commanders mentally rehearsed marches and attacks using flags, markers, and other symbols to assess troop dispositions and anticipate possible enemy maneuvers. The connection with modern military modeling is evident: both historically and today, its primary purpose has remained unchanged – to replace the uncertainty and risks of real combat with systematic analysis, reduce uncertainty, and identify weaknesses in

operational plans before the commencement of military operations. Although modern modeling differs significantly in terms of speed, accuracy, and scale, its fundamental objective remains the same: to support informed military decision-making through the systematic analysis of potential courses of action.

The relevance of this study lies in examining the historical development of military modeling from the era of Ancient China to the beginning of the twentieth century. The article analyzes the approaches employed by prominent military commanders to model forthcoming military operations, examines the key features of the first professional military conflict simulation system, *Kriegsspiel*, and reviews the scientific contributions of twentieth-century military scholars to the development of military modeling theory and practice.

In the military history of the pre-modern period, modeling consisted of creating simplified representations of the battlefield, terrain, or forthcoming military operations. Such models enabled commanders to anticipate possible developments, evaluate alternative courses of action, and select the most effective means of accomplishing the assigned mission. Material forms of military modeling included topographic terrain models (the so-called «sand tables»), whose use is documented in Han Dynasty China, as well as schematic maps depicting terrain features and troop dispositions, prepared on papyrus, parchment, and other media using conventional military symbols [1]. Alongside these physical models, mental modeling was also widely employed. Based on available intelligence concerning the enemy and the terrain, commanders mentally projected the likely course of battle, analyzed the probable actions of both opposing forces, and selected the most appropriate course of military action. In essence, this approach represented an early form of simulation-based military modeling founded on the systematic analysis of possible battlefield scenarios.

Functionally, these models served two principal purposes: diagnostic and predictive. The diagnostic function involved identifying potential vulnerabilities – such as weaknesses in logistical support or exposed flanks – during the planning stage of a campaign, thereby enabling commanders to reduce potential losses through the timely reallocation of forces and resources. The predictive function was achieved by evaluating alternative courses of action. For example, *The Art of War* by Sun Tzu describes a method of comparing opposing forces according to factors such as numerical superiority, troop morale, and terrain. This approach may be regarded as an early form of matrix-based analysis, in which changes in one parameter required corresponding adjustments to the overall tactical plan [2]. A major limitation of these early models was their static and linear nature, as they did not account for random or unforeseen factors, including adverse weather conditions, panic among troops, or delays in communication. Nevertheless, the fundamental principle of military modeling remained unchanged: the construction of a simplified representation of the battlefield reduced the complexity of the operational environment, enabled a more rapid assessment of the situation, and supported more informed decision-making than reliance solely on experience or intuition.

In classical military thought, military modeling existed in two principal forms: as a formalized system of preliminary analytical assessment and as a material representation of the battlefield. One of the earliest and most systematic approaches is presented in Sun Tzu's *The Art of War* (6th–5th centuries BC). In the opening chapter, entitled *Laying Plans* (also translated as *Initial Estimations*), Sun Tzu introduces five fundamental factors – the Way (Dao), Heaven, Earth, the Commander, and Method and Discipline – that must be evaluated before military

operations commence [3,4]. He subsequently proposes comparing the opposing sides using seven evaluation criteria in order to determine their relative strengths and weaknesses. This procedure can be regarded as a prototype of matrix-based analysis, whereby a comparative assessment of advantages and disadvantages was used to estimate the probability of victory before the first engagement. This methodology closely corresponds to contemporary concepts of military situational modeling, in which the preliminary quantitative and qualitative assessment of key variables – such as logistics, troop morale, and command effectiveness– reduces operational uncertainty and improves the quality of planning and decision-making [5,6].

A notable example of spatial military modeling can be found in the tactical planning associated with Hannibal Barca during the Second Punic War. In this case, modeling involved accounting for dynamic natural factors to support the execution of an unconventional maneuver. According to the account of Polybius, the Carthaginian commander Hamilcar Barca (Hannibal's father), during the campaign against the mercenaries, observed that under a particular wind direction a sandbar formed at the mouth of the Medjerda River, making the river fordable. This empirical observation became the basis for an operational decision: exploiting temporary changes in the terrain as a controllable tactical factor enabled the Carthaginian forces to bypass the enemy's fortified position without relying on existing routes of communication [7]. Thus, early military modeling represented a pragmatic combination of abstract analytical reasoning–such as assessing the balance of forces – and detailed consideration of terrain characteristics, with the commander acting as an analyst who integrated disparate information into a coherent forecast of the likely course of military operations.

In the scholarly literature, military modeling during the era of Genghis Khan is primarily examined through the perspective of intelligence collection and analytical activities that formed the foundation of strategic forecasting. Based on an analysis of *The Secret History of the Mongols*, researchers J. Soyombo and J. Tuvshintur reconstruct a military information management system that incorporated intelligence on terrain, the enemy's methods of warfare, the condition of communication routes, and troop morale [8,9]. This system enabled Genghis Khan and his commanders to develop mental models of forthcoming campaigns by evaluating not only the quantitative strength of opposing forces but also dynamic factors, including seasonal changes in the terrain and the enemy's probable routes of withdrawal. Such an approach can be regarded as an early prototype of situational modeling, in which intelligence information was integrated into a predictive assessment of alternative battlefield scenarios long before direct military engagement.

During the Early Modern period, military modeling became increasingly formalized, particularly in the strategic planning of Napoleon Bonaparte and his opponents. According to contemporary reconstructions of Napoleon's campaigns, he extensively employed cartographic analysis and preliminary assessments of the theater of operations to determine the routes of corps movements, calculate force concentration timelines, and identify vulnerabilities in the enemy's flanks [10,11]. In contrast, according to historical sources, Mikhail I. Kutuzov employed a different approach to military modeling, one based on the consideration of spatial, temporal, and climatic factors. During the campaign of 1812, he deliberately avoided seeking decisive battles and instead adopted a strategy that took into account the gradual deterioration of

Napoleon's army caused by the passage of time, logistical difficulties, and geographical conditions [12,13]. Referred to by his contemporaries as a strategy based on "profound deliberation," this approach can be interpreted as a multivariable model in which Kutuzov sought to predict not only the movements of his own forces but, more importantly, the progressive exhaustion of the enemy.

Tactical military modeling reached one of its highest levels of development in the military doctrine of Alexander V. Suvorov, who formulated the well-known principle of «accurate judgment, speed, and assault». In this context, «accurate judgment» should be understood not merely as visual estimation but as the commander's ability to rapidly construct a mental model of the battlefield by taking into account terrain, enemy dispositions, marching time, and potential decisive points of engagement. Suvorov consistently advocated an offensive strategy and deliberately trained his troops under conditions that closely resembled actual combat, enabling soldiers to act in accordance with previously rehearsed operational scenarios [14,15]. Consequently, military modeling in Suvorov's doctrine was not regarded as a static planning exercise but as a dynamic decision-making process in which rapid command decisions and the psychological preparedness of troops compensated for the enemy's numerical superiority and transformed tactical improvisation into a controlled and purposeful process.

One of the most significant milestones in the evolution of military modeling was the development of the professional war game *Kriegsspiel* in Prussia at the beginning of the nineteenth century. Unlike chess, the new system simulated actual combat conditions by incorporating topographic maps, scaled terrain representations, rules governing troop movement, weapon characteristics, maneuver execution times, and elements of uncertainty. Historians of military modeling generally regard *Kriegsspiel* as the first professional military conflict simulation system to be officially incorporated into officer education and training. By allowing military personnel to repeatedly evaluate alternative operational scenarios without risking lives or materiel, the system significantly enhanced the quality of officer training and improved military decision-making.

The professional war game *Kriegsspiel* (German for «war game») was developed in Prussia in the early nineteenth century and became the first systematic military modeling tool to be officially adopted for the training of military officers. Its development is associated with two members of the noble von Reisswitz family: Georg Leopold von Reisswitz (father) and Georg Heinrich Rudolf Johann von Reisswitz (son). The first prototype, consisting of a tactical game played on a three-dimensional sand terrain model, was demonstrated before the Prussian royal court between 1811 and 1812. However, it was the younger Reisswitz – a decorated combat veteran who was awarded the Iron Cross in 1813–who fundamentally transformed the system. He replaced the cumbersome sand-table model with topographic maps produced at a scale of 1:8,000, introduced a rigorous turn-based procedure in which each turn represented two minutes of real time, and incorporated mechanisms designed to simulate the «fog of war» and the uncertainty inherent in battlefield conditions. In 1824, the system was officially presented to the Chief of the Prussian General Staff, General Karl von Müffling, under the title Anleitung zur Darstellung militärischer Manöver mit dem Apparat des Kriegsspiels ("Instructions for the Representation of Military Maneuvers Using the Kriegsspiel Apparatus"). Impressed by the demonstration, von Müffling reportedly declared, «This is not a game; it is a

school of war!» His endorsement marked the beginning of the institutionalization of Kriegsspiel as a mandatory component of officer education and training in the Prussian Army [16,17].

The fundamental principles of *Kriegsspiel* determined its considerable educational and analytical value. The game was organized as a «double-blind» process involving two opposing sides and an umpire, who received written orders from the players, interpreted them while accounting for communication delays, and moved military units on the map, revealing only the information that would have been available to commanders under actual battlefield conditions [16,17]. To calculate combat losses and engagement outcomes, Reisswitz relied on statistical data presented in Gerhard von Scharnhorst's *Über die Wirkung des Feuergewehrs* (*On the Effectiveness of Firearms*, 1813), in which weapon effectiveness was quantitatively expressed as a function of firing range and weapon type [18,19]. To incorporate uncertainty and reflect the inherent variability of combat, specially designed dice with modifiers based on force ratios, terrain characteristics, and troop conditions were introduced into the simulation [20,21]. This approach enabled the modeling of probabilistic rather than deterministic outcomes, preventing the game from becoming a purely mechanical mathematical exercise and training future commanders to make decisions under conditions of incomplete and uncertain information. The practical results achieved through the application of *Kriegsspiel* were highly significant for military science. The system proved to be not only an effective training tool for developing tactical decision-making skills but also a valuable instrument for testing historical hypotheses and planning military operations [22]. The widespread adoption of *Kriegsspiel* within the Prussian officer corps and its subsequent introduction into the armed forces of other countries, including Russia, the United Kingdom, and the United States, is regarded in military historiography as one of the factors that contributed to the organizational and tactical superiority of the Prussian Army during the wars of the second half of the nineteenth century, including the Franco-Prussian War of 1870–1871.

Furthermore, the early twentieth century witnessed substantial advances in the mathematical modeling of combat operations. These pioneering studies established the scientific foundations of modern military science and operations research by formalizing the fundamental principles governing combat and introducing rigorous mathematical methods for predicting the outcomes of military engagements.

The Russian military scholar Mikhail P. Osipov, who later became one of the pioneering figures in the history of military modeling, developed one of the earliest mathematical theories of combat. In 1915, he published a series of papers in the journal *Voennyy Vestnik* (*Military Herald*), in which he formulated the fundamental principles of combat modeling and introduced mathematical models of two-sided engagements. Osipov developed a system of differential equations describing changes in troop strength during combat. His models, commonly referred to as the square law of combat, demonstrated that military superiority depends not merely on the numerical strength of opposing forces but on the square of that strength. Consequently, defeating an opponent with twice the number of forces would require weapons approximately four times more effective. Osipov was also the first to emphasize that the coefficients of his equations should depend on factors such as troop training, terrain characteristics, and troop morale, thereby laying the foundation for incorporating qualitative variables into quantitative models of combat [23,24].

At approximately the same time, in 1916, the British engineer Frederick W. Lanchester published similar mathematical models for analyzing aerial combat. Although Osipov's work preceded that of Lanchester, this class of mathematical models became widely known in Western scientific literature as the Lanchester models [23,25].

Formalized approaches to combat analysis had also appeared prior to Osipov's work. As early as 1906, Ya. Karpov, in his article *Tactics of Fortress Artillery*, proposed mathematical relationships for evaluating the effectiveness of fortress defense by linking the characteristics of shrapnel fire with infantry movements. These ideas were subsequently expanded by P. Nikitin, who broadened the range of weapon systems considered and developed recommendations for their optimal allocation [24].

Based on the foregoing analysis, it can be concluded that the beginning of the twentieth century marked a turning point in the evolution of military modeling. During this period, military modeling evolved from the intuitive methods employed by ancient military commanders into rigorous mathematical theories that continue to provide the foundation for many contemporary strategic and tactical analytical models.

References:

1. Fan Ye. Hou Han Shu [History of the Later Han Dynasty]. Available at: https://www.vostlit.info/Texts/Dokumenty/China/III/Fan_E/text1.htm (accessed 20 July 2026).
2. Sun Tzu. Iskusstvo voiny [The Art of War]. Translated by N. I. Konrad. Available at: https://realaiki.ru/wp-content/uploads/2018/12/iskusstvo_voini.pdf (accessed 20 July 2026). (In Russian).
3. Sun Tzu. Traktat o voennom iskusstve [Treatise on the Art of War]. Translated by P. A. Samsonov. Minsk: Popurri; 2015. Available at: https://books.yandex.uz/books/OazPurVv/read-online (accessed 6 July 2026). (In Russian).
4. Sun Tzu. Iskusstvo voiny [The Art of War]. Available at: https://www.litres.ru/book/sun-czy/iskusstvo-voyny-48748203/chitat-onlayn (accessed 6 July 2026). (In Russian).
5. Sun Tzu. Iskusstvo voiny [The Art of War]. Available at: https://books.yandex.uz/@b5199968992/books/QiNn0eDb/quotes (accessed 6 July 2026). (In Russian).
6. Gorbylev A. Put' nevidimykh. Podlinnaya istoriya nin-dzyutsu [The Way of the Invisible: The True History of Ninjutsu]. Available at: https://readli.net/chitat-online/?b=79758&pg=8 (accessed 6 July 2026). (In Russian).
7. Pobeda Gamil'kara pri Makare [Hamilcar's Victory at the Macar River]. Available at: https://sv-scena.ru/Buki/Gannibal.8.html#Q675-Pobyeda-Gamiljjkara-pri-Makarye (accessed 6 July 2026). (In Russian).
8. V Mongolii dokazyvayut aktual'nost' drevnikh metodov "Tainoi razvedki Chingiskhana" [Mongolia Demonstrates the Relevance of Genghis Khan's Ancient Intelligence Methods]. Available at: https://ulan.mk.ru/social/2025/06/30/v-mongolii-dokazyvayut-aktualnost-drevnikh-metodov-taynoy-razvedki-chingiskhana.html (accessed 6 July 2026). (In Russian).
9. V Mongolii izdana kniga "Tainaya razvedka Chingis-khana" [The Book "The Secret Intelligence of Genghis Khan" Published in Mongolia]. Available at:

https://burunen.ru/news/society/138051-v-mongolii-izdana-kniga-taynaya-razvedka-chingis-khana (accessed 6 July 2026). (In Russian).
10. Grand Battery: Rules and Regulations for Napoleonic Wargaming. Available at: https://books.google.com.sg/books?id=Iub_0AEACAAJ (accessed 6 July 2026).
11. Leipzig – The Battle of Nations: A Wargamer's Guide to the Battle of Leipzig 1813. Available at: https://books.google.com.sg/books?id= CmAIEQAAQBAJ (accessed 6 July 2026).
12. Russkii biograficheskii slovar'. Tom 9 [Russian Biographical Dictionary. Vol. 9]. St. Petersburg; 1903. Available at: https://ru.wikisource.org/wiki/ Страница:Русский_биографический_словарь. Том_9_(1903).djvu/650 (accessed 6 July 2026). (In Russian).
13. Sherstobitova I. Metapredmetnoe soderzhanie romana L.N. Tolstogo "Voina i mir" na urokakh raznykh predmetnykh oblastei [Metasubject Content of Leo Tolstoy's Novel War and Peace in Teaching Different Academic Disciplines]. In: Otkrytaya metodika: v poiskakh utrachennogo ili shag v budushchee? [Open Methodology: In Search of the Lost or a Step into the Future?]. Proceedings of the III All-Russian Scientific and Practical Conference. St. Petersburg; 2019. pp. 217–226. (In Russian).
14. Letunovskii V. Menedzhment po Suvorovu: nauka pobezhdat' [Management According to Suvorov: The Science of Victory]. Moscow: Alpina Publisher; 2012. 298 p. ISBN 978-5-9614-1778-4. (In Russian).
15. Bardakhchiev Yu. Russkii geroizm. Fenomen Suvorova [Russian Heroism: The Suvorov Phenomenon]. Sut' Vremeni Newspaper. 2017;232. Available at: https://rossaprimavera.ru/article/russkiy-geroizm-fenomen-suvorova (accessed 6 July 2026). (In Russian).
16. Playing War: The Development and Early Use of Kriegsspiel. Available at: https://www.iheart.com/podcast/269-footnoting-history-46372329/episode/ playing-war-the-development-and-early-294118814 (accessed 6 July 2026).
17. Georg von Reisswitz. Available at: https://en.wikipedia.org/wiki/ Georg_von_Reisswitz (accessed 6 July 2026).
18. Klöffler M. The Reisswitz Kriegsspiel: Cartographic Aspects, 1820–1850. Available at: https://kartdok.staatsbibliothek-berlin.de/servlets/MCRFileNodeServlet/kartdok_derivate_00000441/Klöffler_Cartography_Kriegsspiel_2023_08_28.pdf (accessed 6 July 2026).
19. Vintjes J. "Not a Game but a School of War": Notes on the Early History of Prussian-German Kriegsspiel. Available at: https://data.isiscb.org/p/isis/citation/ CBB875043219 (accessed 6 July 2026).
20. Available at: https://researchspace.auckland.ac.nz/server/api/core/ bitstreams/e6b33cb9-0016-4318-93db-7db43f6126b9/content#38#18. (accessed 6 July 2026).
21. Wheatley K. Engineering under Uncertainty: A Genealogy of the Fog of War. PhD Dissertation. University of Auckland; 2022. Available at: https://researchspace.auckland.ac.nz/server/api/core/bitstreams/e6b33cb9-0016-4318-93db-7db43f6126b9/content (accessed 6 July 2026).

22. Lawrence K. Kriegsspiel: How a 19th-Century War Game Changed History. Available at: https://militaryhistorynow.com/2019/04/19/kriegsspiel-how-a-19th-century-war-game-changed-history (accessed 6 July 2026).
23. Shumov V. Analiz funktsii pobedy po opytu strategicheskikh operatsii Velikoi Otechestvennoi voiny [Analysis of the Victory Function Based on the Experience of Strategic Operations During the Great Patriotic War]. Voprosy bezopasnosti [Security Issues]. 2020;(3). DOI:10.25136/2409-7543.2020.3.33092. (In Russian).
24. Yusupov R, Ivanov V. Iz istorii matematicheskogo modelirovaniya boevykh deistvii v Rossii (1900–1917 gg.) [From the History of Mathematical Modeling of Combat Operations in Russia (1900–1917)]. Informatika i avtomatizatsiya [Informatics and Automation]. 2023;22(5):947–967. (In Russian).
25. Mityukov N. Opredelenie zhertv voin cherez lanchesterskie modeli [Estimating War Casualties Using Lanchester Models]. Available at: https://cyberleninka.ru/article/n/opredelenie-zhertv-voyn-cherez-lanchesterskie-modeli (accessed 6 July 2026). (In Russian).