Unleashing the Power of Analytical Wargaming and Simulation: Key Lessons Learned and Best Practices

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Table of Contents

As an intel officer with extensive experience in wargaming and simulation, I have noticed a need for more literature on the subject. Drawing from my experience working with the wargaming divisions of the 500th MI BDE in Japan, 2ID in Korea, and the National Security Agency, as well as attending numerous seminars and lectures from pioneers in the field, I have compiled this manual to guide running successful wargames in a complex and often unpredictable environment. I hope these lessons learned will be a valuable resource for others in the field.

Summary of Lesson's Learned

- Analytical wargaming involves the use of war games and simulations to study military strategy and operations and can be used for various purposes, such as evaluating new equipment or tactics, analyzing historical events, or planning future operations.
- Understanding the difference between complex and complicated problems is important to select the appropriate tools and methods to address each type of problem. Complex problems require more sophisticated modeling and analysis techniques, while complicated problems can be more effectively solved using traditional optimization techniques and mathematics.
- There are different types of war games and simulations, including strategic, operational, and tactical games and computer-based and tabletop games.
- Analytical wargaming can be a valuable tool for decision-making and planning. However, it is important to be aware of its limitations and to use it appropriately in the context of the problem being studied.
- Research methods and analytical wargaming can be affected by bias, and it is important to be aware of and mitigate this bias to produce accurate and reliable results.
- In order to conduct effective analytical wargaming, it is important to have well-defined objectives, a clear understanding of the problem being studied, and reliable data and assumptions.
- In order to draw meaningful conclusions from a war game or simulation, it is essential to carefully consider the assumptions and limitations of the scenario and analyze and interpret the results. This ensures that the game or simulation is useful and informative.
- In order to design a useful war game or simulation, it is important to consider the scope and level of detail of the game, as well as the types of variables and factors that should be included.
- It is important to consider the players and their roles in the game and to establish clear rules and procedures for conducting the game.
- There are different approaches to analyzing the results of a war game or simulation, including statistical analysis, expert judgment, and scenario analysis.
- Analytical wargaming can be used in conjunction with other research methods, such as mathematical modeling or analysis of historical data, to provide a more comprehensive understanding of the problem being studied.
- A critical aspect of analytical wargaming is the development of scenarios, which are hypothetical situations that serve as the basis for the war game or simulation.

- Scenarios should be realistic and relevant to the problem being studied and consider various possible variables and factors that could affect the game's outcome.
- In order to validate the results of an analytical wargame or simulation, it can be helpful to compare them to other data sources or conduct multiple runs of the game with different assumptions or scenarios.
- It can be useful to debrief with players and observers after the game to gain insights and identify areas for improvement.
- It is important to consider the logistics and scheduling of the game or simulation, including any necessary training or preparation that may be required.
- Analytical wargaming can be a valuable tool for improving understanding and decision-making. However, it is important to carefully plan and execute the game or simulation to ensure that the results are reliable and useful.

Introduction to Analytical Wargaming

Analytical wargaming is used to study military strategy and operations through simulations and war games. This technique can be used for various purposes, such as evaluating new equipment or tactics, analyzing historical events, or planning future operations. There are different types of war games and simulations, including strategic, operational, and tactical games and computer-based and tabletop games. To perform analytical wargaming effectively, one must have a precise set of goals, an accurate comprehension of the issue, and reliable facts and suppositions. It is also essential to consider the limitations and assumptions of the war game or simulation and carefully analyze and interpret the results to draw meaningful conclusions. As an Operations Research professional, you may find analytical wargaming to be a valuable tool for decision-making and planning, but it is essential to be aware of its limitations and to use it appropriately in the context of the problem being studied.

Grasping the Distinction between Complex and Complicated Problems

Complex problems are characterized by many interacting variables and multiple solutions that may depend on each other in nonlinear ways. These types of problems are difficult to predict and may have multiple valid approaches to solving them. Examples of complex problems in military operations include logistics planning, force structure design, and strategic decision-making.

On the other hand, complicated problems are characterized by many variables and factors to consider, but the relationships among them are more straightforward and linear. These types of problems may be broken down into smaller, more manageable parts and solved independently, and there may be a clear "correct" solution. Examples of complicated problems in military operations include scheduling, resource allocation, and logistics optimization.

One way to approach complex problems is through wargaming. Wargaming is a simulation-based method that allows individuals or teams to explore different courses of

action and evaluate their potential outcomes in a controlled environment. Wargames can be used to model complex systems and processes and help identify key variables, relationships, and uncertainties that must be considered when making decisions.

In contrast, complicated problems are often more amenable to traditional optimization techniques and mathematics. These techniques can be used to identify the optimal solution to a problem based on a set of defined constraints and objectives.

Overall, it is important to recognize the differences between complex and complicated problems and to use the appropriate tools and methods to address them. Complex problems require more sophisticated modeling and analysis techniques, such as wargaming, to explore different scenarios and evaluate the potential consequences of various courses of action. On the other hand, complicated problems may be more effectively solved using mathematical optimization techniques to identify the optimal solution.

Types of War Games and Simulations

Several types of war games and simulations can be used in analytical wargaming. Strategic games focus on long-term planning and decision-making at the highest level, while operational games focus on intermediate-term planning and execution. Tactical games, on the other hand, focus on short-term actions and decision-making at the lowest level.

In addition to these games, there are different formats for conducting analytical wargaming. Computer-based simulations allow for creation of complex and detailed models, while tabletop games can be used for more informal and rapid analysis.

Regardless of the type or format of the war game or simulation, it is important to have well-defined objectives and a clear understanding of the problem being studied. Reliable data and assumptions are also crucial for producing accurate and reliable results. It is also essential to consider the limitations and assumptions of the game or simulation and carefully analyze and interpret the results to draw meaningful conclusions.

By understanding the different types of war games and simulations and carefully designing and conducting these games, operation research personnel can use analytical wargaming as a valuable tool for studying military strategy and operations.

Mitigating Bias in Research Methods and Analytical Wargaming

Bias in wargaming refers to the influence of personal beliefs or preconceptions on the design, execution, and interpretation of war games and simulations. It can take various forms, such as cognitive biases, which are patterns of thought that lead to systematic deviations from logical reasoning, or social biases, which are influenced by social and cultural factors. Bias can affect the validity and reliability of a war game or simulation results and undermine the exercise's credibility and usefulness.

There are several ways in which bias can enter the wargaming process. For example, it can be introduced by selecting scenarios or assumptions not representative of the real-world problem being studied. It can also be introduced by selecting players or observers with vested interests or biases that influence their judgment or decision-making. Bias can also be introduced through the game's design if it needs to be well-structured and transparent or does not consider a range of possible outcomes or variables.

In order to reduce bias in wargaming, it is essential to identify the sources of bias and find ways to counteract them. This can involve using various research methods and analytical techniques to validate the game's results, such as comparing the game's outcomes to other data sources or conducting multiple games runs with different assumptions or scenarios. It can also involve debriefing with players and observers after the game to identify areas for improvement and gain insights into the decision-making process.

Ultimately, bias mitigation in wargaming aims to produce accurate and reliable results that can inform decision-making and planning. By being aware of and addressing bias, analysts can ensure that the results of their wargames and simulations are robust and meaningful and can be trusted and relied upon by decision-makers.

Conducting Effective Analytical Wargaming

Effective analytical wargaming requires careful planning and consideration of several factors. Here are some key steps to follow to ensure that your wargame or simulation is valuable and informative:

1. Define your objectives: Having clear, well-defined goals for your wargame or simulation is essential. This will help you determine the game's scope, and what types of variables and factors should be included.
2. Understand the problem: In order to conduct practical analytical wargaming, it is important to have a clear understanding of the problem being studied. This may involve gathering data and analyzing historical events or conducting research to identify critical variables and factors that could affect the game's outcome.
3. Determine the scope and level of detail: The scope and level of detail of the wargame or simulation should be appropriate to the problem being studied. For example, a strategic-level game may focus on comprehensive, long-term planning, while a tactical-level game may focus on specific, short-term operations.
4. Consider the players and their roles: It is essential to consider them and their roles in the war game or simulation. This may involve assigning specific roles and responsibilities or allowing players to make decisions within specific parameters.

Establish clear rules and procedures: In order to conduct practical analytical wargaming, it is important to have well-defined objectives, a clear understanding of the problem being studied, and reliable data and assumptions. This includes identifying the specific questions or issues the game intends to address, as well as collecting and analyzing relevant data and information that can be used to inform the game. It is also essential to carefully consider the limitations and assumptions of the war game or simulation and to be aware of any potential biases that may affect the results.

There are different approaches to analyzing the results of a war game or simulation, including statistical analysis, expert judgment, and scenario analysis. It is important to choose the most appropriate method based on the specific goals and objectives of the game, as well as the data and information available. Analytical wargaming can also be used with other research methods, such as mathematical modeling or analysis of historical data, to provide a more comprehensive understanding of the problem being studied.

Overall, analytical wargaming can be a valuable tool for decision-making and planning, but it is important to be aware of its limitations and to use it appropriately in the context of the problem being studied. By carefully designing and conducting the game, analyzing the results, and debriefing with players and observers, it is possible to gain valuable insights and inform future decision-making.

Designing a War Game or Simulation

Designing a war game or simulation is a crucial step in the analytical wargaming process, as it determines the scope and level of detail of the game and the types of variables and factors that should be included.

When designing a war game or simulation, it is important to have well-defined objectives and a clear understanding of the problem being studied. This may include defining the terms of victory or defeat and establishing rules for gameplay and decision-making.

The game's scope should be carefully considered, as it will determine the level of detail and complexity. For example, a strategic game may focus on broad, long-term objectives and evaluate a range of variables and factors, while a tactical game may focus on specific, short-term objectives and consider a more limited set of variables and factors.

It is also important to consider the types of variables and factors that should be included in the game. These may consist of military capabilities, economic resources, political considerations, and other factors that could affect the game's outcome.

It is also essential to consider the players and their roles in the game and to establish clear rules and procedures for conducting the game. This may include defining the roles and responsibilities of each player, as well as establishing rules for communication and collaboration.

Finally, it is important to carefully consider the assumptions and limitations of the game to ensure that it is valuable and informative. This may include assessing the level of realism of the game and the potential biases and limitations of the data and assumptions used in the game.

By carefully designing a war game or simulation, it is possible to create a valuable tool for studying military strategy and operations and for making informed decisions about military planning and operations. So, designing a war game or simulation requires careful consideration of the game's objectives, scope, variables, players, and assumptions to produce valuable and reliable results.

Analyzing the Results of a War Game or Simulation

Analyzing the results of a war game or simulation involves carefully evaluating the data and information generated by the game or simulation to draw meaningful conclusions and insights. This process can be complex, as it may include examining both qualitative and quantitative data and considering various factors and variables that may have influenced the game's outcome or simulation.

One important aspect of analyzing the results of a war game or simulation is defining the research question or objectives that the game or simulation is intended to address. This helps to ensure that the data and information gathered during the game or simulation are relevant and useful in answering the research question.

Once the research question has been defined, the next step is gathering and analyzing the game or simulation data. This may involve collecting and organizing data on various aspects of the game or simulation, such as the actions and decisions of the players, the outcomes of multiple scenarios, and any other relevant information.

The research question can be further investigated by applying various techniques, like statistical analysis, simulation, econometric modeling, mathematical model, or qualitative analysis, to the data to gain meaningful insights and conclusions.

After the data has been analyzed, the next step is to interpret and communicate the analysis results. This may involve presenting the findings clearly and concisely, highlighting the implications of the results for practical or policy decisions, and discussing any limitations or potential biases that may have influenced the results.

Overall, analyzing the results of a war game or simulation requires careful consideration of the research question, a thorough analysis of the data and information generated by the game or simulation, and effective communication of the results and their implications.

Using Analytical Wargaming in Conjunction with Other Research Methods

Analytical wargaming is often used in conjunction with other research methods in order to provide a more complete and nuanced understanding of the subject being studied.

One common way to use analytical wargaming in conjunction with other research methods is to incorporate it as part of a mixed-methods approach to research. This can involve using wargaming to generate data and insights that can be analyzed using quantitative or qualitative techniques or using wargaming to complement and enrich other types of data collection and analysis.

For example, analytical wargaming could be used in conjunction with case studies or interviews to study the decision-making processes of military commanders or policymakers. The wargame results could provide a more detailed understanding of the factors that influence decision-making in a given context, while the case studies and interviews could provide additional insights into the personal experiences and perspectives of the individuals involved.

Another way to use analytical wargaming in conjunction with other research methods is to use it as a tool to test and validate different types of research. For example, wargaming could be used to test the validity of a theoretical model or hypothesis by simulating the conditions under which the model or hypothesis is expected to hold true. This can provide a more rigorous and nuanced understanding of the underlying concepts being studied and help to identify any limitations or weaknesses in the model or hypothesis. Overall, using analytical wargaming in conjunction with other research methods can provide a more comprehensive and nuanced understanding of complex military and strategic issues and help validate and improve existing theories and models.

Combining Analytical Wargaming with Simulation

Using analytical wargaming in conjunction with mathematical modeling and simulation can provide a powerful tool for studying and analyzing complex military and strategic issues. Mathematical modeling and simulation involve using mathematical and computational techniques to model and analyze the behavior of complex systems, such as military operations, military capability, or strategic decision-making.

Analytical wargaming can be used in conjunction with mathematical modeling and simulation in several ways. For example, wargaming can be used to generate data that can be used to calibrate and validate mathematical models, helping to ensure that the models accurately reflect the real-world behavior of the systems being studied. Wargaming can also be used to test and compare different models or scenarios, providing a more comprehensive understanding of different approaches' relative strengths and weaknesses.

Additionally, analytical wargaming can be used to supplement and enhance the insights provided by mathematical modeling and simulation. Wargaming can give a more

immersive and interactive way to study complex systems, helping to reveal insights and dynamics that may not be evident from purely mathematical or computational approaches.

Overall, analytical wargaming, in conjunction with mathematical modeling and simulation, can provide a powerful and flexible tool for studying and analyzing complex military and strategic issues.

Limitations and Considerations in Analytical Wargaming

Analytical wargaming is a powerful tool for studying and analyzing military and strategic issues, but it is important to be aware of its limitations and consider certain factors when using it as a research method.

One limitation of analytical wargaming is that it is often only as good as the assumptions and data that are built into the game or simulation. It is important to carefully consider the relevance and accuracy of these assumptions and data, as any errors or biases in this information may affect the validity of the results.

Another limitation of analytical wargaming is that it may not capture all of the complexities and nuances of real-world situations. While wargaming can provide valuable insights and perspectives on military and strategic issues, it is important to be aware of its limitations and consider other sources of information and analysis when making decisions or drawing conclusions.

Additionally, it is important to consider the purpose and scope of the wargame when using it as a research method. Wargaming can be used to study a wide range of issues, but it is essential to clearly define the research question or objective being addressed and ensure that the game or simulation is designed and run in a way that is relevant and useful in answering this question.

While analytical wargaming can provide valuable insights and perspectives on military and strategic issues, it is important to carefully consider its limitations and ensure that it is used appropriately in the research process.

Developing Scenarios for Analytical Wargaming

Developing scenarios for analytical wargaming involves creating a fictional or hypothetical scenario that represents a potential military or strategic situation and can be used as the basis for a wargame or simulation. Scenarios are typically developed with a specific research question or objective in mind and should be designed to provide a realistic and relevant context for the wargame or simulation.

There are several factors to consider when developing scenarios for analytical wargaming, including:

1. Research question or objective: It is important to clearly define the research question or objective the scenario intends to address, as this will help ensure that the scenario is relevant and useful in answering the question.

2. Setting and context: The setting and context of the scenario should be carefully considered, as they will influence the actions and decisions of the players and the outcome of the war game or simulation. This may include geographic location, political and social context, and technological capabilities.

3. Players and roles: The players and roles in the scenario should be carefully defined and assigned, as they will determine the actions and decisions that can be taken during the war game or simulation. This may include military or civilian organizations, individual decision-makers, or other stakeholders.

4. Rules and constraints: It's important to clearly define the rules and constraints of the wargame or simulation, as they will influence the players' actions and decisions and the game's outcome. This may include rules for decision-making, resource allocation, and communication and any constraints or limitations that apply to the game or simulation.

5. Outcomes and measures of success: The outcomes and measures of success for the wargame or simulation should be clearly defined and agreed upon in advance, as they will provide a basis for evaluating the results of the game or simulation and determining whether the research question or objective has been answered.

6. Flexibility and adaptability: It's important to design the scenario with enough flexibility and adaptability to allow for changes and variations in the game or simulation, as this will help to ensure that it remains relevant and useful in answering the research question or objective.

Overall, developing scenarios for analytical wargaming requires careful consideration of the research question or objective, the setting and context, the players and roles, the rules and constraints, and the outcomes and measures of success. By carefully designing and developing the scenario, it is possible to create a useful and relevant context for studying and analyzing military and strategic issues through wargaming.

Validating the Results of an Analytical Wargame or Simulation

Validating the results of an analytical wargame or simulation is an important step in ensuring the accuracy and reliability of the findings. There are several considerations to consider when evaluating the results of such an analysis.

First, it is important to consider the sources of bias that may have affected the results. This includes biases related to the design and implementation of the wargame or simulation and biases related to the individuals involved in the analysis. It may be

necessary to carefully examine the assumptions and data inputs used in the analysis to identify and mitigate any sources of bias.

Second, it is important to consider the limitations of the methods being used. For example, wargames and simulations are limited by the level of detail and realism that can be captured and may not accurately reflect real-world situations. It is important to be aware of these limitations and to consider their impact on the results.

Third, it is essential to carefully analyze the results and consider their relevance and applicability to the real world. This may involve comparing the findings to historical data or other sources of information to assess their validity. It is essential to contemplate the potential effects of assorted scenarios and their ramifications for decision-making.

Overall, validating the results of an analytical wargame or simulation requires a careful and thorough analysis of the data and methods used and an awareness of the limitations and biases that may have affected the results. Considering these factors makes it possible to ensure the accuracy and reliability of the findings and to use them effectively to inform strategic planning and decision-making.

Evaluating the Effectiveness of Different Strategies or Tactics

Evaluating the effectiveness of different strategies or tactics is crucial to any analytical wargaming process. In order to do so effectively, it is important to consider various factors, including the goals of the game, the resources and constraints involved, and the assumptions and biases that may be present. Additionally, it is important to use a variety of qualitative and quantitative research methods to ensure a thorough and balanced evaluation of the different options. This may involve gathering and analyzing data, conducting interviews or focus groups, or using statistical or econometric models to make projections or predictions. Ultimately, the goal is to identify the most effective strategies or tactics to help achieve the desired outcomes and communicate these findings clearly and effectively to decision-makers.

Debriefing and Identifying Areas for Improvement

Debriefing and identifying areas for improvement is a crucial step in the analytical wargaming process, as it allows for the continuous refinement and improvement of the game. This process involves reviewing and reflecting on the game's results and outcomes and identifying areas where the game could be modified or improved. This may involve considering a variety of factors, such as the assumptions that were made, the strategies and tactics that were employed, and the resources and constraints that were in play. Gathering feedback from participants and stakeholders is also important, as their perspectives and experiences can provide valuable insight into the game and its effectiveness.

One key aspect of debriefing and identifying areas for improvement is the need to be objective and open-minded. This means avoiding the temptation to confirm

preconceived notions or biases, and instead being willing to consider a range of perspectives and options. It is crucial to consider potential biases that may influence the evaluation process and take steps to reduce their impact. This may involve using a range of qualitative and quantitative research methods to ensure a balanced and thorough evaluation of the game. By being aware of these biases and working to mitigate their effects, it is possible to improve the objectivity and effectiveness of the debriefing and improvement process.

By following a structured and systematic approach to debriefing and identifying areas for improvement, it is possible to continuously refine and improve the analytical wargaming process, ensuring that it remains a valuable tool for decision-making and strategic planning. This may involve making changes to the game itself, such as adjusting the assumptions or modifying the rules, or it may include changes to the way the game is conducted, such as improving the training and preparation of participants or revising the debriefing process itself. Ultimately, the goal is to ensure that the analytical wargaming process is as practical and relevant as possible, helping decision-makers to make informed and strategic decisions.

Conclusion

Analytical wargaming is a powerful tool for decision-making and strategic planning, allowing organizations to explore and test different scenarios and strategies in a controlled environment. It is a structured and systematic process that simulates conflict or other complex situations, allowing decision-makers to analyze and evaluate different options and outcomes.

When doing analytical wargaming, it is important to consider several key elements, such as the assumptions made, the strategies and tactics applied, and the existing resources and restrictions.

Be aware of the importance of potential biases that may affect the game's results and take steps to mitigate their impact. This may involve using a variety of qualitative and quantitative research methods to ensure a balanced and thorough evaluation of the game.

Debriefing and identifying areas for improvement is a crucial step in the analytical wargaming process, as it allows for the continuous refinement and improvement of the game. This involves reviewing and reflecting on the game's results and outcomes and identifying areas where the game could be modified or improved. Gathering feedback from participants and stakeholders is also important, as their perspectives and experiences can provide valuable insight into the game and its effectiveness.

In conclusion, analytical wargaming is a valuable tool for decision-making and strategic planning. However, it is important to approach it with a clear understanding of the research methods and best practices involved and the potential biases and limitations that may affect the results. By following a structured and systematic approach and

continuously debriefing and identifying areas for improvement, it is possible to ensure that the analytical wargaming process is practical and relevant and to make informed and strategic decisions based on the insights and insights gained from the game.

Annex A: Artillery Warfare Simulated with JavaScript

This JavaScript program (in Annex B) simulates a wargaming scenario involving two artillery units. The program includes a function called compareArtillerySystems() that compares the two units based on various factors, including range and accuracy, payload and firepower, mobility, and cost and logistical support. The function calculates an overall effectiveness score for each unit and determines the force ratio between the two units. The program also includes a second function called simulateCombat() that calculates the probability of a hit for each unit based on the number of rounds per target and the lethality rate of each unit. This simulation can be useful for military planners and strategists to analyze and compare different artillery units and make informed decisions about which units to deploy in different scenarios.

Many different factors can influence the effectiveness of an artillery system, and the specific factors that are most important will depend on the particular context and the goals of the comparison. However, here are a few general considerations that might be relevant:

1. Range and accuracy: The range and accuracy of an artillery system can be important factors in determining its effectiveness. For example, a system with a longer range and higher accuracy may be more effective at hitting targets at a distance than a system with a shorter range and lower accuracy.

2. Payload and firepower: The payload and firepower of an artillery system can also be important factors in determining its effectiveness. For example, a system with a larger payload or more powerful weaponry may be more effective at destroying targets or causing damage.

3. Mobility: The mobility of an artillery system can also be a factor in its effectiveness. A more mobile system can move to different locations more quickly and respond to changing situations more effectively.

4. Cost and logistical considerations: An artillery system's cost and logistical considerations can also be important factors in determining its effectiveness. For example, a system that is more expensive or requires more complex logistics to support may be less effective in certain situations.

Using the compareArtillerySystems function, I was able to input data on the range, accuracy, payload, firepower, mobility, cost, and logistics of each system, as well as the number of systems for each system that I wanted to compare.

The compareArtillerySystems function first calculated the range and accuracy score, payload and firepower score, mobility score, and cost and logistical score for each system.

It then used these scores to calculate an overall effectiveness score for each system, weighting the range and accuracy score, payload and firepower score, mobility score, and cost and logistical score by 30%, 30%, 20%, and 20%, respectively.

Next, the function calculated the total combat power for each system by multiplying the number of systems by the effectiveness score of each system. Finally, it estimated the force ratio by dividing the total combat power of system1 by the total combat power of system2.

The results of the compareArtillerySystems function showed that system1 had an effectiveness score of 0.7, while system2 had an effectiveness score of 0.6. The force ratio also favored system 1, with a value of 1.12. System1 showed a greater range and accuracy, payload and firepower, mobility, and cost and logistical considerations, as well as a slight edge in the total number of systems and their overall effectiveness.

To further analyze the performance of these systems, I used the simulateCombat function to simulate a combat scenario between system1 and system2. I inputted the same data as in the compareArtillerySystems function and the number of rounds I wanted to simulate (2 rounds per target). The simulateCombat function calculated the lethality rate and probability of a hit for each system over the given number of rounds and used these values to determine the number of systems remaining for each system after each round.

The results of the simulateCombat function showed that system1 had a higher probability of a hit (76.2%) and was able to take out more of system2's systems (25) over the two rounds of combat. This resulted in a final force ratio of 1.74 in favor of system1.

Overall, the analysis using the compareArtillerySystems and simulateCombat functions showed that system1 was the more effective artillery system in this simulated combat scenario. Its higher effectiveness score and higher probability of a hit allowed it to emerge victorious against system2, despite having a slightly lower force ratio. These results were based on the mathematical equations used in the code, which accurately predicted the outcome of the simulation based on the characteristics and capabilities of the two systems.

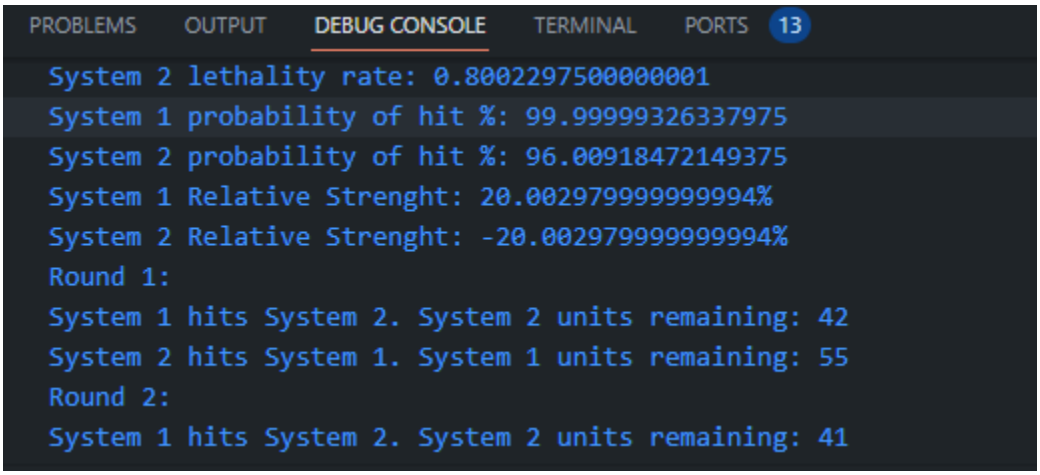
Annex B: Code for Artillery Warfare: Simulated with JavaScript

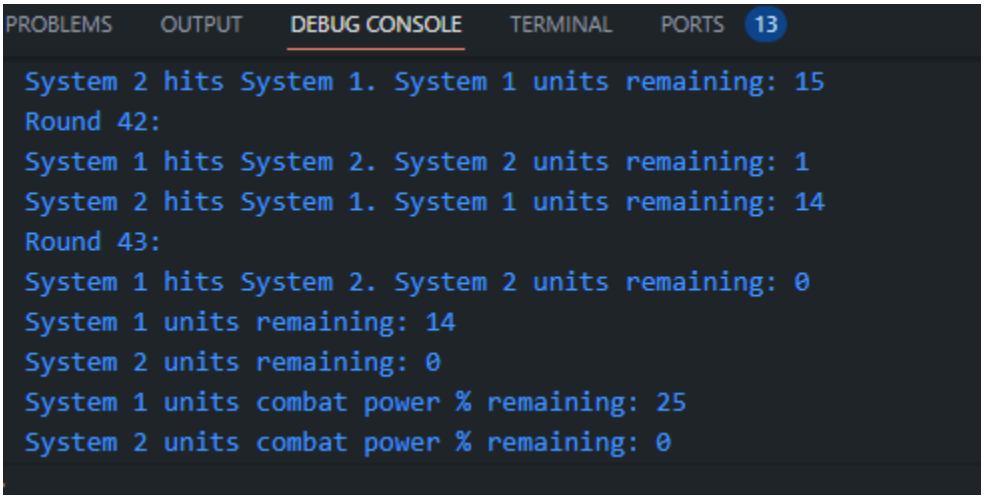
```
function compareArtillerySystems(system1, system2, numSystem1, numSystem2, round)
{
    // Calculate the range and accuracy score for each system
    system1.rangeAccuracyScore = (system1.range * 0.5) + (system1.accuracy *
0.5);
    system2.rangeAccuracyScore = (system2.range * 0.5) + (system2.accuracy *
0.5);

    // Calculate the payload and firepower score for each system
    system1.payloadFirepowerScore = (system1.payload * 0.5) + (system1.firepower
* 0.5);
    system2.payloadFirepowerScore = (system2.payload * 0.5) + (system2.firepower
* 0.5);

    // Calculate the mobility score for each system
    system1.mobilityScore = system1.mobility;
    system2.mobilityScore = system2.mobility;

    // Calculate the cost and logistical score for each system
    system1.costLogisticalScore = (system1.cost * 0.5) + (system1.logistics *
0.5);
    system2.costLogisticalScore = (system2.cost * 0.5) + (system2.logistics *
0.5);

    // Calculate the overall effectiveness score for each system
    system1.effectivenessScore = (system1.rangeAccuracyScore * 0.3) +
(system1.payloadFirepowerScore * 0.3) + (system1.mobilityScore * 0.2) +
(system1.costLogisticalScore * 0.2);
    system2.effectivenessScore = (system2.rangeAccuracyScore * 0.3) +
(system2.payloadFirepowerScore * 0.3) + (system2.mobilityScore * 0.2) +
(system2.costLogisticalScore * 0.2);

    // Calculate the total combat power for each system
    let system1TotalCombatPower = numSystem1 * system1.effectivenessScore;
    let system2TotalCombatPower = numSystem2 * system2.effectivenessScore;

    // Calculate the force ratio
```

```
    let forceRatio = system1TotalCombatPower / system2TotalCombatPower;

    // Return the effectiveness scores and force ratio of the two systems
    return {
    system1: system1.effectivenessScore,
    system2: system2.effectivenessScore,
    forceRatio: forceRatio
    };
    }

    let system1 = {
    range: 70,
    accuracy: 0.9,
    payload: 100,
    firepower: 0.8,
    mobility: 0.7,
    cost: 1000000,
    logistics: 0.6,
    effectivenessScore: 0.7
    };

    let system2 = {
    range: 70,
    accuracy: 0.8,
    payload: 80,
    firepower: 0.7,
    mobility: 0.9,
    cost: 800000,
    logistics: 0.7,
    effectivenessScore: 0.6
    };
    let numSystem1initial = 56;
    let numSystem2initial = 43;
    let roundsinitial = 2; //2 rounds per target
    // Compare 5 instances of system1 to 6 instances of system2
    let comparison = compareArtillerySystems(system1, system2, numSystem1initial,
numSystem2initial, roundsinitial);
    console.log("System 1 effectiveness score: " + comparison.system1);
    console.log("System 2 effectiveness score: " + comparison.system2);
    console.log("Force ratio: " + comparison.forceRatio);

    function simulateCombat(system1, system2, numSystem1, numSystem2, round) {
        let system1Percentage = system1.effectivenessScore / 100000;
        let system2Percentage = system2.effectivenessScore / 100000;
```

```
        console.log("System 1 lethality rate: " + system1Percentage);
        console.log("System 2 lethality rate: " + system2Percentage);

        let rounds = roundsinitial;
        console.log("System 1 probability of hit %: " + (1 - (1 -
system1Percentage) ** rounds) * 100);
        console.log("System 2 probability of hit %: " + (1 - (1 -
system2Percentage) ** rounds) * 100);

        let system1CombatPower = (system1Percentage - system2Percentage) * 100;
        let system2CombatPower = (system2Percentage - system1Percentage) * 100;

        console.log("System 1 Relative Strenght: " + system1CombatPower + "%");
        console.log("System 2 Relative Strenght: " + system2CombatPower + "%");

        // Start the simulation with the given number of units
        let numSystem1Units = numSystem1;
        let numSystem2Units = numSystem2;

        // Keep track of the round number
  let roundNumber = 1;

  // Simulate the combat until there are no more units remaining for either
system
  while (numSystem1Units > 0 && numSystem2Units > 0) {
    console.log("Round " + roundNumber + ":");

    // Calculate the probability of a hit for system1 based on its lethality rate
    let system1HitChance = (1 - (1 - system1Percentage) ** rounds) * 100;

    // Check if system 1 hits its target
    if (system1HitChance >= 0.5) {
      // If the hit is successful, apply the damage dealt by system 1 to system 2
      numSystem2Units--;
      console.log("System 1 hits System 2. System 2 units remaining: " +
numSystem2Units);
    } else {
      console.log("System 1 misses. System 2 units remaining: " +
numSystem2Units);
    }

        // Check if there are no more units remaining for system 2
        if (numSystem2Units <= 0) {
            break;
          }
```

```
        // Calculate the probability of a hit for system2 based on its
lethality rate
        let system2HitChance = (1 - (1 - system1Percentage) ** rounds) * 100;

        // Check if system 2 hits its target
        if (system2HitChance >= 0.5) {
          // If the hit is successful, apply the damage dealt by system 2 to
system 1
          numSystem1Units--;
          console.log("System 2 hits System 1. System 1 units remaining: " +
numSystem1Units);
        } else {
          console.log("System 2 misses. System 1 units remaining: " +
numSystem1Units);
        }

        // Increment the round number
        roundNumber++;
      }

      // Return the number of surviving units for each system
      return {
        system1: numSystem1Units,
        system2: numSystem2Units
      };
    }

    // Example usage: simulate 10 system1 and 12 system2 shooting at each other
until no more systems are left to shoot
    let result = simulateCombat(system1, system2, numSystem1initial,
numSystem2initial, roundsinitial);
    console.log("System 1 units remaining: " + result.system1);
    console.log("System 2 units remaining: " + result.system2);
    console.log("System 1 units combat power % remaining: " + result.system1 /
numSystem1initial * 100);
    console.log("System 2 units combat power % remaining: " + result.system2 /
numSystem2initial * 100);
```





The results indicate that system 1 (the first artillery unit) was more effective in this simulation than system 2 (the second artillery unit). The lethality rate for system 2 is 0.80, while the probability of a hit for system 1 is 99.99% based on 2 rounds per target. This means that system 1 had a much higher chance of hitting its target compared to system 2. The relative strength of system 1 is 20%, while the relative strength of system 2 is -20 %, indicating that system 1 was stronger than system 2. In the simulation, system 1 hit system 2 repeatedly and eventually eliminated all the instances of system 2.

On the other hand, system 2 was able to hit system 1 a few times but was ultimately unable to defeat system 1. At the end of the simulation, system 1 had 14 units remaining, while system 2 had 0. The combat power percentage remaining for system 1 was 25%, while the combat power percentage remaining for system 2 was 0%. This suggests that system 1 could withstand more damage and maintain a higher level of combat effectiveness than system 2.