# A Computer-Assisted Multi-Domain Operations Wargaming Concept

**Philip Muurmans, Koen Bezemer, Armon Toubman**
**Royal Netherlands Aerospace Centre - NLR**
**Amsterdam, The Netherlands**
**{Philip.Muurmans, Koen.Bezemer, Armon.Toubman}@nlr.nl**

**ABSTRACT**

Nowadays, there are increased threats from adversaries taking a multi-domain approach. Multi-Domain Operations (MDO) was developed to understand multi-domain threats, thereby mitigating their impact. However, current modelling and simulation (M&S) developments are trailing behind the advancements of the MDO concept. How should defense organizations prepare themselves against the challenges of multi-domain warfare? In this paper, we present a concept for computer-assisted MDO wargaming. Our concept shows how M&S can be applied to emulate real-world MDO complexity in a wargame, while leveraging computational power to facilitate the decision maker's understanding of this complexity. While the implementation of the MDO concept in military organizations is ongoing, we focus on developing M&S support. M&S has been applied to military operations for many years. MDO brings about new forms of complexity which raises new M&S challenges. By applying a concept development and experimentation (CD&E) approach to the application of M&S for MDO, we create new insights about the utilization of M&S and Artificial Intelligence (AI) technology. We introduce a simplified command and control wargame loop and enrich it to support MDO decision making. The virtual world in the wargame represents real-world complexity to stimulate MDO-oriented decision making and to research how the decision maker can be supported using M&S tooling as well as Generative AI. Our concept enables rapid prototyping to discover the needs and opportunities for decision makers within a complex MDO environment. This enables a defense organization to shape their implementation of the MDO concept and increase their resilience against multi-domain threats.

**ABOUT THE AUTHORS**

**Philip Muurmans** is an R&D engineer at the department of Training and Simulation at NLR. He holds a M.Sc. in Innovation, Defense and Security from the Swedish Defense University. His main research focus has been on the simulation of Multi-Domain Operations (MDO).

**Koen Bezemer** is an M&S engineer at the department of Training and Simulation at NLR. He holds a B.Sc. in Aerospace Engineering and has spent the last 4 years working in flight and computational mechanics. At NLR he works on several projects related to Battle Labs, Multi-Domain Operations and Tactical Flight Simulation.

**Armon Toubman** is an R&D engineer at the department of Training and Simulation at NLR. He holds a PhD in Artificial Intelligence from Leiden University and has authored over 25 publications presented at various international conferences and symposia. Since 2013, his main focus has been on research into behavior models for tactical simulations. His current research interests include the development of simulation concepts with Artificial Intelligence applications for supporting activities pertaining to operational art.

# A Computer-Assisted Multi-Domain Operations Wargaming Concept

**Philip Muurmans, Koen Bezemer, Armon Toubman**
**Royal Netherlands Aerospace Centre - NLR**
**Amsterdam, The Netherlands**
**{Philip.Muurmans, Koen.Bezemer, Armon.Toubman}@nlr.nl**

## INTRODUCTION

The Multi-Domain Operations (MDO) concept involves the integrated planning and execution of operations across the land, air, sea, space, and cyber domains, as well as coordination with non-military activities (cf. Evensen et al., 2024; Flack et al., 2020; NATO Allied Command Transformation, 2022; Scott, 2022). The goal is to deliver converging effects that achieve strategic objectives, enhancing the effectiveness of military operations. By synchronizing military and non-military activities, MDO aims to achieve a synergistic effect, where the combined impact is greater than the sum of its parts. However, as a concept, MDO does not prescribe how this manner of operating is achieved, let alone how personnel should be trained in its ways.

The traditional military experiential training tool is the wargame (cf. Development, Concepts and Doctrine Centre, 2017). Wargames are games focused on military thinking and decision-making. The introduction of the MDO concept brings new complexities to wargaming. The need to integrate and synchronize effects across multiple domains, as well as coordinate with non-military activities, requires wargames to account for a broader range of variables and interactions. This increased complexity can make it challenging to develop accurate and reliable models, and to interpret the results of wargaming exercises. As a result, wargaming methodologies must evolve to accommodate the nuances of MDO, incorporating advanced technologies and analytical techniques to support more comprehensive and realistic simulations. However, the MDO concept does not prescribe how these technologies and techniques should be applied. Therefore, practical experimentation is required.

Although wargames do not need to be computer-assisted, recent advances in Generative Artificial Intelligence (GenAI) provide opportunities for the development of rich environments and scenarios, as well as for refereeing ("adjudicating" in wargaming terms) and keeping track of the state of the world. In this paper, we present a concept for a computer-assisted turn-based MDO wargame. Since there is little guidance available in the literature on what constitutes a good MDO wargame, the concept is developed with a rapid prototyping approach in order to explore the various solutions in a practical manner. By presenting a functional prototype instead of a blank canvas to military stakeholders, discussions about requirements are guided from "where do we start" to "where do we go from here".

The paper is structured as follows. We briefly discuss wargaming and MDO, and introduce the concept of *common situational understanding* (CSU), which we view as a major opportunity for computer-assisted wargaming in an MDO context (see section *Background*). Next, we present our computer-assisted wargaming concept (see section *Computer-Assisted MDO Wargaming Concept*). The concept centers around a generic command and control (C2) wargame, to which we apply modelling & simulation (M&S) as well as artificial intelligence (AI) in order to enhance the wargame in two ways: (1) we enrich the simulation world that drives the wargame, in order to introduce the complexities required for an engaging MDO scenario; and (2) we add CSU components to aid the decision maker in the wargame with making sense of the (simulated) world. Next, we discuss the capabilities and limitations (see section *Discussion*). Finally, we conclude the paper with an outlook on future work (see section *Conclusion*).

## BACKGROUND

Wargaming is a methodology used to explore complex scenarios in the context of military planning (Appleget, 2021). It involves role-playing and interactive discussions to anticipate and prepare for potential outcomes. By mimicking real-world situations, wargaming enables participants to evaluate risks and develop effective strategies to reach their end state. Traditionally, wargames require a supporting staff to facilitate the gaming process, such as staff concerned with operations (e.g., staff that physically moves units after commands have been given) or adjudication (viz. determining the outcomes of orders given by the players). Advances in simulation technology have enabled *computer-assisted* wargaming, in which the computer performs many of the tasks of the supporting staff, thereby improving the efficiency, accuracy, and objectivity of wargaming exercises (see, e.g., Bruvoll et al., 2022; Hodický et al., 2020; Schwartz et al., 2020). It is important to emphasize a key difference between wargaming and simulation: as mentioned by Hodický et al. (2020), computer-assisted wargaming should not be driven towards the increasing application of quantitative techniques since the complexity of problems, the creativity in decision making, and the often limited repetitions within wargaming do not support the required fidelity to gain credible, reproducible experimental results. In contrast, simulation (perhaps with automated decision-making models) may indeed lead to significant and reproducible quantitative output.

Related work on MDO wargaming and/or simulation is scarce. Marler (2023) advocates for the development of training tools while the doctrine is still being worked out by defense organizations. Flack et al. (2020) developed a card game to educate military personnel on the use of capabilities in a multi-domain conflict. Evensen et al. (2024) propose a set of requirements for synthetic environments aimed at simulating MDO conflicts. On the real-world side of the spectrum, Doyle et al. (2025) report the lessons learned from MDO exercises across US Army echelons. Informed by these findings and the lack of guidance on what constitutes a good MDO wargame, we attempt a rapid prototyping approach in this paper.

Two key ideas driving the concept are the notions that GenAI may aid in (a) constructing and moderating the environment in which the wargame is situated, but also in (b) helping a decision maker make sense of the environment using an MDO-oriented framing. GenAI represents a transformative paradigm in machine learning, enabling the creation of complex and realistic data across various domains (Gatla et al., 2024). Regarding (a), GenAI models such as Large Language Models (LLMs) excel at processing and generating texts, while other models are capable of generating and interpreting images and video. An LLM is applied later in the paper to fulfil various functions in our wargaming concept.

We refer to idea (b) as Common Situational Understanding (CSU). In the context of an MDO wargame, we define CSU as the understanding one has about the events and entities that are presented in a common operational picture (COP). In our approach we simplified the decision-making process by only focusing on a single decision maker. However, the role of the decision maker can also be fulfilled by a staff made up of multiple roles. When there is more than one decision maker it is important that everyone has a similar understanding of the meaning and reasoning behind the events and entities in the simulation world. As mentioned by Marchetti (2018), we perceive, experience, feel, and think from a unique perspective, therefore no stimulus is perceived neutrally.

In our view, the simplest approach to CSU aids is to look at established warfighting concepts. For example, the Centre of Gravity (CoG) theory can be used to gain a new perspective within the MDO concept (Lehtoaro, 2023). The CoG theory highlights that there is an optimal way to win a military confrontation by using one's own critical strengths against the critical weaknesses of the opponent. This raises the question of how we can identify and understand these critical strengths and weaknesses across the three dimensions of MDO: physical, virtual, and cognitive. The second concept is the PMESIIxASCOPE matrix. PMESIIxASCOPE stands for the dimensions *Political, Military, Economic, Social, Information, Infrastructure* and the possible targets *Area, Structures, Capability, Organization, People, Equipment*. The matrix was proposed by Scott (2022) as a model to capture the various tangible and intangible elements that are present in the MDO environment. By combining such concepts with the generative power of GenAI, we aim to simplify the creation of CSU tooling.

## COMPUTER-ASSISTED MDO WARGAMING CONCEPT

In this section, we present our computer-assisted MDO wargaming concept. We first describe the goals that the concept is aiming to fulfil (see subsection *Goals of the Concept*). Next, we give an overview of the concept (see subsection *Concept Overview*) and discuss its three major components.

This section is based on a previous publication (Muurmans et al., 2024), expanded and reframed to focus on wargaming applications.

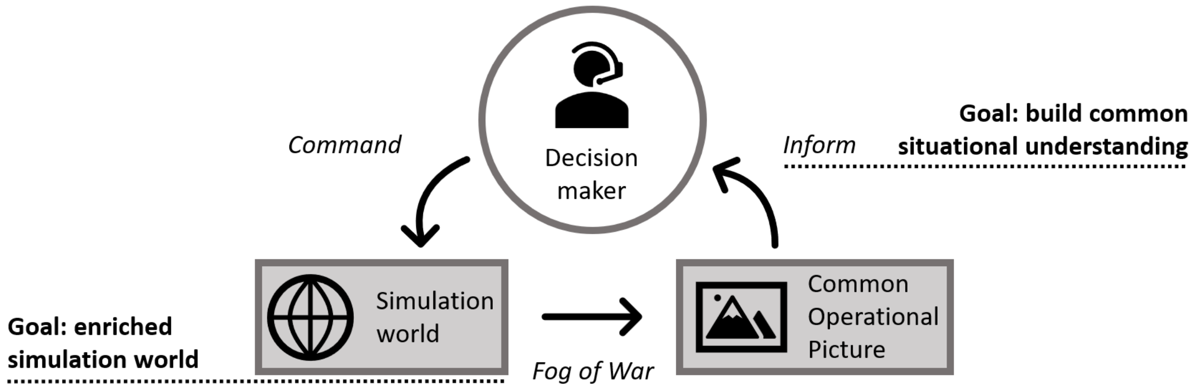



**Figure 1. A Generic Computer-Assisted Command and Control Wargame Loop**

### Goals Of The Concept

Figure 1 shows a diagram of a generic computer-assisted wargame. The decision maker is informed by a Common Operational Picture (COP), which presents information about the state of the world. The decision maker issues a command, which is processed by the simulation world. From the updated state of the world, a new COP is generated. The state of the simulation world is filtered by a ‘fog of war’ function, which filters out information that the decision maker is not (yet) privy to.

We identify two challenges to turn the wargame depicted in Figure 1 into a MDO wargame. First, MDO was formulated as a concept to make sense of and act in a complex environment. However, building wargame scenarios and letting them play out in a manner that represent real-world complexity are time and resource intensive processes. This is the case even for traditional scenarios with blue units and red units placed on a world map. The desire for MDO-worthy, complex scenarios with interconnected elements aimed at stimulating the decision maker only increases the intensity of these processes. The second challenge lies in the feedback from the COP to the decision maker. As the wargame’s virtual world grows more complex, we expect the decision maker to experience increased difficulty in making sense of the world and making informed decisions. This may lead to sub-optimal engagement with the wargame (i.e., frustration) (Nakamura & Csikszentmihalyi, 2009).

Based on these challenges, we formulate two design goals for the MDO wargaming concept. The first goal is to enrich the simulation world, to make the world fit for use in a MDO scenario. The second goal is to aid the understanding of decision makers. Next, we discuss our approach to achieving the two goals.

### Enriching The Simulation World

MDO as a concept is aimed at making sense of, and acting in a complex threat environment. Replicating the complexity present in the real world requires steps beyond traditional constructive simulation. In this paper, we discuss enrichments introduced in our simulation framework: (1) the generation of a narrative, (2) the automatic generation of additional entities and structures, and (3) the integration of effect models. Element 1 and 2 are discussed further below in Component A of Figure 2, element 3 is discussed in Component B of Figure 2.

### Building Common Situational Understanding

GenAI is used to build our CSU by breaking down the MDO battlespace in tangible elements that can be understood by the decision maker. For this process we used the PMESIIxASCOPE matrix. This matrix is used to interpret the consequences of actions made in the simulation world. Inspired by Scott (2022), the PMESIIxASCOPE matrix categorizes all the entities that are present in the simulation world. By understanding the role and characteristics of each entity we can discover the needs and opportunities for decision makers within a complex MDO environment.

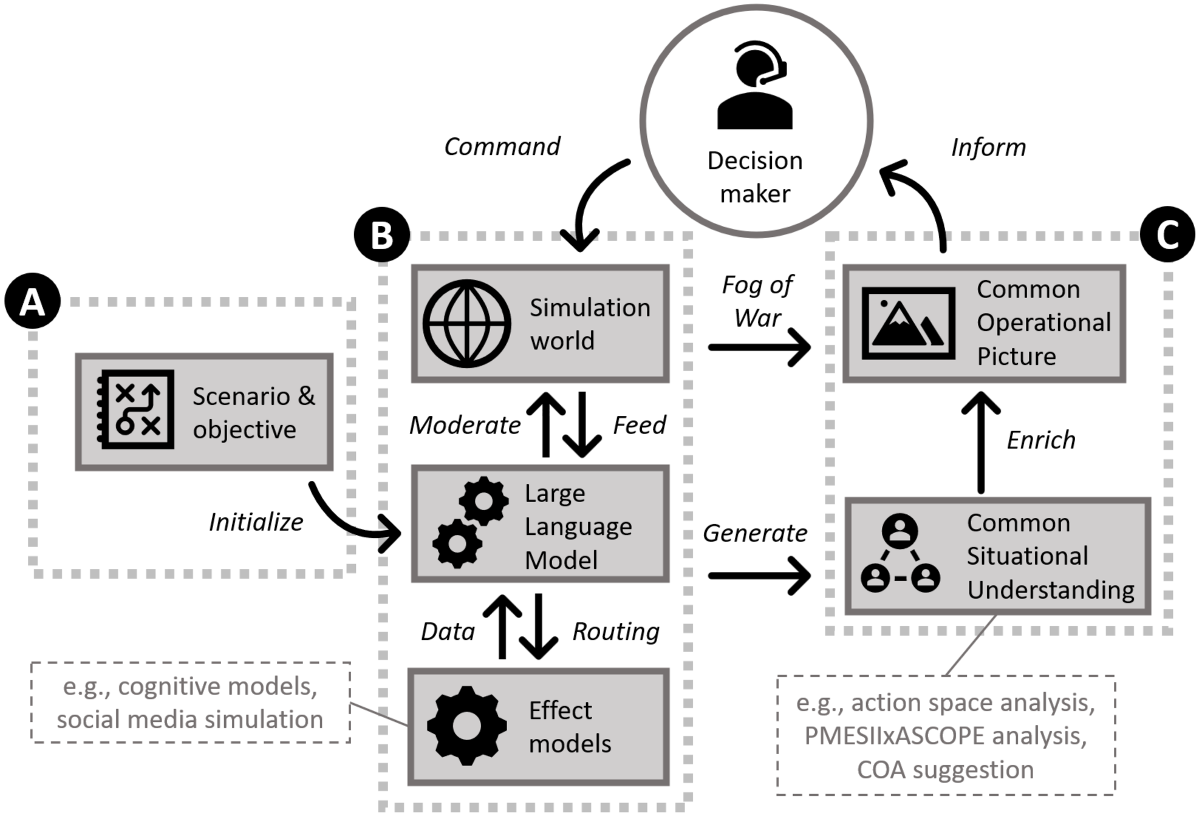



**Figure 2. Overview of the Computer-Assisted MDO Wargaming Concept**

**Concept Overview**

Figure 2 shows an overview of the concept. We divide the concept into three components: component A, initialization of the simulation world & forming the narrative; component B, governing the simulation world and the command-and-control loop; and component C, for building common situational understanding. Below, each component is discussed separately.

***Component A: Initialization of the Simulation World & Forming the Narrative***

A coherent narrative is essential for simulation environments in MDO. It provides context and establishes a shared understanding of the scenario, objectives, and rules of engagement among stakeholders. A clear narrative ensures all participants are aligned and working towards common goals. Furthermore, a well-defined narrative outlines the operational environment, defines key events and milestones, and establishes the scope of the simulation.

The narrative also introduces rational actors (e.g. state actors, military figures), each with their own interests and agendas. These actors may attempt to influence the simulation's proceedings, shaping the outcome to their advantage. By incorporating such actors, the simulation can mimic the complexities of real-world human interaction, where multiple entities interact and try to achieve their objectives.

As discussed above, the narrative provides information upon which decisions can be based, but also informs the effects of those decisions, whether calculated by a human or computer adjudicator (see Component B). Developing a relevant (i.e., addressing the goal of the wargame) and interesting (i.e., providing a stimulating decision space) scenario is a complex task. In some ways, the task is akin to writing the outline of a novel, with settings, characters, motivations, and important events. Developing scenarios for computer-assisted wargames may, to some extent, also involve programming the scenario into a computer program. This may involve the development of representations of terrain, assets, behavior, and so on.

Traditionally, computer programs follow explicit instructions. Component A has the ability to expand the human-generated narrative using GenAI. This leads to an expanding world, resulting in a cluttered decision space and decreasing the prevalence of obvious actions. The introduction of GenAI provides opportunities for co-developing scenarios. Opportunities are:

- Adding pattern-of-life elements
- Writing and assigning behavior models
- Improvising and expanding upon narrative elements
- Adding relevant layers in the MDO environments (for example cyber infrastructure)

To start the wargame, all of the above factors are combined in a single document (the narrative). The narrative is then provided to the LLM to form the basis for turn zero: the opening situation in the wargame. When these steps are performed, the wargame is initialized and ready to commence.

***Component B: Simulation World and Command-and-Control Loop***

The simulation world is a database that holds all relevant information regarding the scenario, entities, and their respective states. Subsequently, the simulation world is the reference point from which the CSU and COP is generated. The simulation world is processed and updated by an LLM, which acts as adjudicator for the wargame. Besides the traditional role of arbitration, the adjudicator in this framework delegates actions to and from effect models.

The framework seeks to recreate the complex and connected MDO world within a simulated wargaming environment. To achieve this, effect models are introduced. Effect models are existing simulators such as computer-generated forces, social media simulators, space simulators, cyber models etc. The effect models are fed by data from the central simulation world and, subsequently, once they have done their calculations, their results are stored back into the simulation world. Collectively, the models form the basis on which the later discussed CSU is formed. Because the adjudicator can reason on the collective results from the effect models, secondary effects (not initially found in the results from the effect models) can be seen and reported to the operator in the CSU. By combining the effect models into the greater simulation world and using the reasoning power of the LLMs, we aim to cover the various dimensions and subsequently generate the interconnected MDO world.

It is important to mention that the contextual use of the LLM is for data routing and logical tasks only. The LLM is not used to directly "influence" the simulation world, for that purpose the effect models are introduced. The collective sum of the effect models generates the simulation world. Another consideration is that state-of-the-art LLMs have shown limitations with logic models and reasoning tasks (Huckle & Williams, 2025). Therefore, the output formatting of the LLM is verified before further use.

The LLM-powered adjudicator fulfills two actions: (1) World Moderation (from the LLM to the simulation world in Figure 2) and (2) Simulation Routing (from the LLM to the Effect Models in Figure 2). World Moderation is the processing and moderation of all entities in the simulation based on scenario context. The LLM will receive context of the battlespace, the factions and the wargaming rules. Using this context the adjudicator will go through the following steps:

1. Gather the user Course of Action (COA) and, using the red force Rules of Engagement (ROE) and fog of war, formulate a COA for the red force
2. Parse the COA for the red force and blue force and pass this information to the Sim Router
3. Process information once the Sim Router is done and update the simulation world
4. Generate post-turn data for the debrief interface and COP interface

The described steps will be performed when the user has generated a COA and is defined as the Command & Control loop. The decision maker generates the COA through the main adjudication window. Within this window, actions and units are selected, and commands are typed into a designated box. The LLM interprets these commands to determine the required actions. Configuration options are also available, allowing users to select relevant effect models for the wargaming session.

Simulation routing is employed to direct the effect models. The router must translate the COAs into simulation actions and subsequently feed result back to the adjudicator. Inspiration for the Sim Router was taken from an existing AI concept called the LLM router. The LLM router, by itself a small general-purpose LLM, is used to effectively route existing prompts to specialized LLMs (Hu et al., 2024). This method is employed by popular AI websites like ChatGPT and Huggingface.

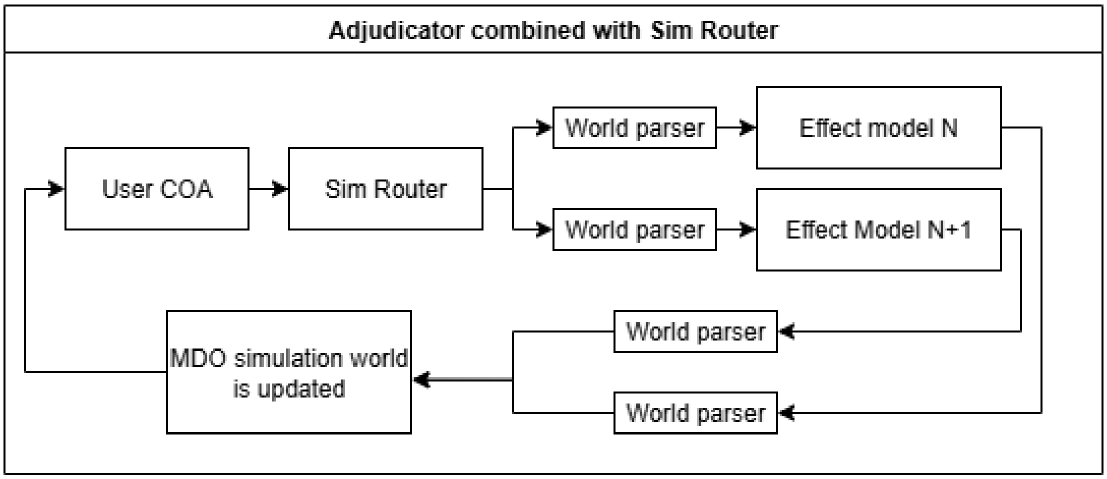



**Figure 3. Simplified Command and Control Loop**

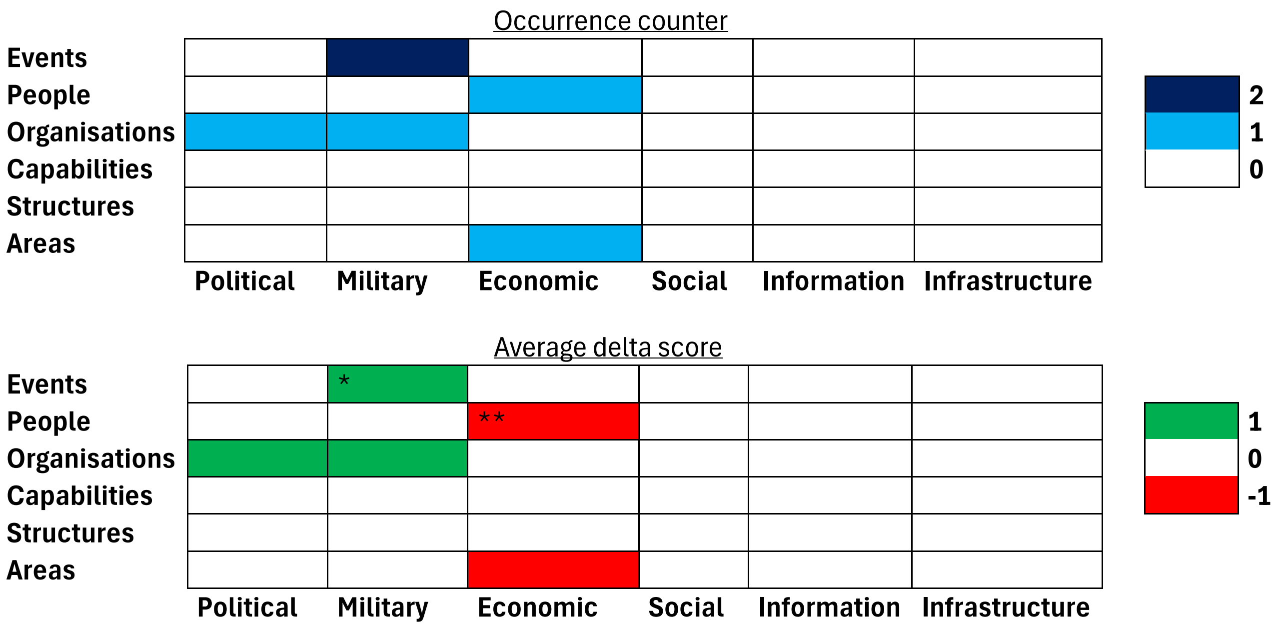
By exchanging the specialized LLMs with simulators, a system is created that can automatically manage the connected simulators. The Sim Router will have all the required information (e.g. data formats, system requirements, required entities) from each connected simulator. Subsequently, the router uses this to disseminate the COA down to simulator actions. Before the data reaches the simulator, it must pass through a simulation world parser. This parser will act as interface between the greater MDO simulation world, the Sim Router, and the specific world of the effect model. This parser must take relevant data from the simulation world and generate relevant data for the domain specific simulator. Inversely, it will also share data with the simulation world once the simulation has completed. Figure 3 shows a simplified loop of the adjudicator with the Sim Router.

***Component C: Common Situational Understanding***

During the world moderation step the LLM interprets the effect of the COA on the entities in the simulation world via the PMESIIxASCOPE matrix. Scott (2022) describes ways to expand on the two-dimensional PMESIIxASCOPE matrix for example by adding a third dimension such as DIME (Diplomacy, Information, Military, Economy). Such additions can help to enhance the matrix's capability to capture MDO complexity. However, it also makes it more difficult for the decision maker and LLM to synchronize their CSU about the MDO simulation world. In the current iteration of the concept, the PMESIIxASCOPE matrix is kept two-dimensional and starts blank for each wargame. This design choice facilitates the team's ability to test the evolving CSU concept with GenAI, allowing for a focused evaluation of the concept's effectiveness.

The CSU is presented through two separate interfaces, the Turn Debrief and Common Operational Picture (COP). Together they build the operator's situational awareness. Post-turn results are presented in the debrief interface, where outcomes are displayed and organized within a PMESIIxASCOPE matrix. This matrix enables results to be interpreted in a neutral manner, independent of their domain-specific context. Results are weighted against the scenario's objective and the user's specified COA, generating a delta result score on a scale from 1 (positive) to -1 (negative). The scoring can be generated from both red and blue forces perspective. The matrix data is generated by the same GenAI that is used to adjudicate the wargame. This is performed by providing the full context of the wargame, the previous turns, the stated objectives of the countries, and the intention of the turn. With this context, the GenAI is asked to assess and categorize the turns actions in the previously defined matrix.

Figure 4 shows an example of the PMESIIxASCOPE matrix from a fictional scenario. In this fictional scenario, Country A is being terrorized by enemy forces that are disguised as fishing boats as well as the presence of frigates from an opposing country. Country A wants to secure their Exclusive Economic Zone (EEZ) so they decide to deny all commercial shipping in the EEZ using maritime and air forces. This action has a positive effect on the political and military efforts of Country A, however it negatively effects the economic status of the area and people living nearby. The “Occurrence counter” matrix shows the amount of occurrences that take place in this turn. The “Average delta plot” shows if the combined occurrences that take place in the cell of the matrix have a positive, neutral or negative effect.




**Occurrence details: Country A successfully escorts opponent frigates and denies commercial shipping in the EEZ using both maritime and air forces. Delta: 1*
***Occurrence details: The blockade of commercial fishing activity in the EEZ negatively influences the local economy. Delta: -1*

**Figure 4. Illustration of the Debrief Interface**

The simulation world is presented through the COP, which offers a 3D view of the battlespace. Figure 5 offers an example of a top-down view of the 3D world. This view spatially situates all units within the context of the simulation world, presenting the world as it would appear in a real-life situation. The fog of war is modeled, with enemy units only revealed after a reconnaissance action is performed. Units that are jammed may be displayed inaccurately, adding to the realism of the simulation environment. Units are geocoded and can “move” depending on their actions and results. Due to the turn-based nature of the simulation, the units remain frozen in the COP until updated by the adjudicator. In Figure 5, see the inclusion of non-military entities such as the Harbour (top left) and the Fishermen (bottom right). These units are integrated in the scenario and are influenceable, either directly or indirectly, by the COAs. Furthermore, an AWACS, a flight of strike fighters, and a frigate are heading for the enemy frigates (red bottom middle).

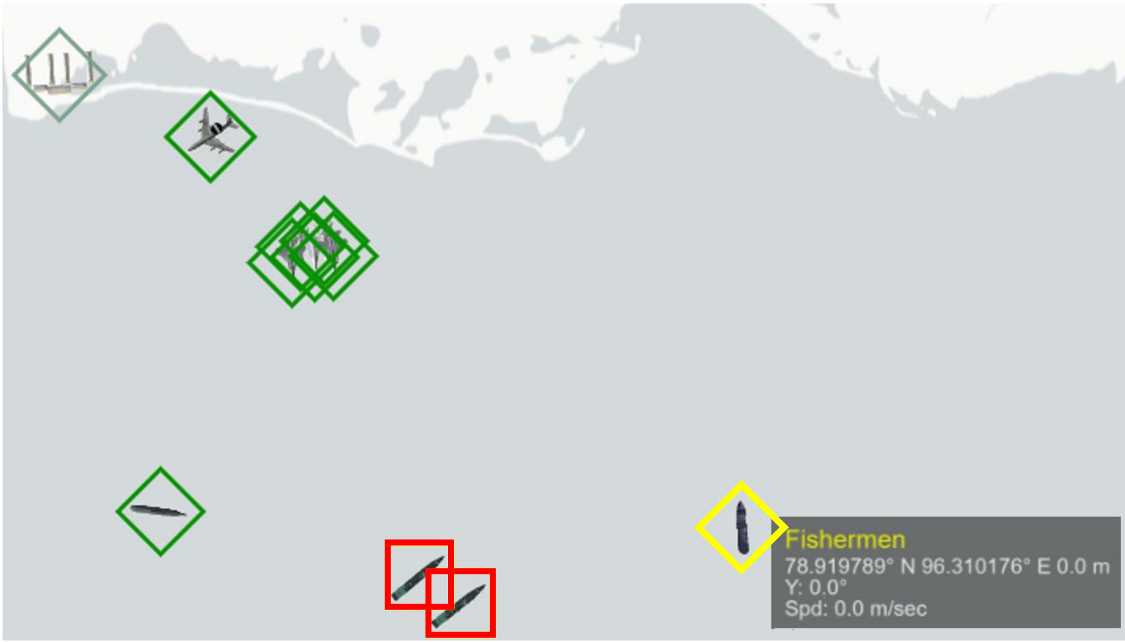


**Figure 5. Common Operational Picture**

**DISCUSSION**

This paper presented a concept for computer-assisted MDO wargaming, aimed at reaching two goals: (1) an enriched simulation world, to represent the complexities in the real world, and (2) facilitate the decision maker's understanding of the decision space.

While doctrine developers and military commands are still discovering the ramifications of applying the complexity of the MDO concept to the complexity of the real world, we believe it is necessary to keep experimenting with simulation and AI technology. This experimentation may not only serve to produce supporting technology (such as a computer-assisted wargame), but may also to help clarify the application of MDO itself by the systematic deconstruction of the problem required for simulation.

The main driver of the framework is the LLM. LLMs are advanced AI systems that generate and manipulate human language, enabling them to perform a wide range of tasks such as text generation, translation, and conversation. In the framework, we make use of an LLM for (a) its capability to analyze literal texts (e.g., in the processing of the scenario and narrative), combined with (b) its ability to interact with precise systems (e.g., the simulation world) as well (c) as the ability to interpret that world and capture that world into soft concepts (e.g., the PMESIIxASCOPE concept).

The use of an LLM opens up the possibility to integrate new data sources into a simulation with minimal manual integration effort. Connections with data sources such as the Janes simulation world (Janes, n.d.) may feed the simulation world with data collected in the real world, adding realism and relevance to the scenarios that are played out. An interesting first approach may be a connection to existing PMESIIxASCOPE data sources, allowing for wargames to start with a substantiated baseline. When the wargame is finished, the PMESII values can be directly compared to the starting values to indicate lasting effects across the operating environments. An example of such an application is provided by Weissenberger (2024), who showed how one can use open-source data to establish realistic PMESII values.

Despite the simulation potential unlocked by the integration of an LLM, the output of generative AI such as LLMs should continue to be regarded with a healthy level of distrust. State-of-the-art models still struggle with logic puzzles and common sense reasoning (Huckle & Williams, 2025). Still, initial experiments have been positive, with the added functionality overshadowing possible reasoning errors. Future validation experiments should indicate to what extent the reasoning capabilities of the LLM support the decision-making process, and at what point the deficiencies of the LLM become detrimental to the wargaming experience.

Three important points of attention for concepts as those presented in the paper are scalability, flexibility, and interoperability. As of yet, the focus of the concept has been on one decision maker in-the-loop. Given the importance the MDO concept gives to the synchronization with various stakeholders and the orchestration of military action, it would be beneficial if the concept can scale to include decision makers in multiple (defense) organizations, as well as on different echelons. This also addresses the flexibility of the concept, as the concept may need to be tuned to allow for the various information needs and command options. On a technical level, the interoperability of the components that constitute the concept may need to be described formally in order to ensure future connections with new components.

## CONCLUSION

For decades, wargaming and simulation solutions have enabled military organizations to practice decision making in safe-to-fail environments. The implementation of MDO calls for similar solutions and environments, especially since the MDO concept was designed to enable more effective operations in the complex situations present in the real world. However, MDO as a whole is difficult to capture in a single simulation or wargame.

In this paper we present a novel computer-assisted wargaming concept that makes use of GenAI to represent real-world complexity for MDO decision making. By letting the GenAI control the wargame update loop, it can utilize the effect models to represent the physical, virtual and cognitive MDO dimensions. We aim to use the effect models to generate the interconnected MDO world. To aid the understanding of the complex MDO scenarios, the concept utilizes existing analytical tools such as the PMESIIxASCOPE matrix, allowing the AI to aid the decision maker with a shared understanding of the operating environment.

Further research is required to realize the concept, both in the depth of the scope of the concept and in the breadth of the concept by possible additions of effect models. Future work will focus on applying the implementation of the concept to particular use cases. It will also include identifying specific end users and aligning the concept with their requirements. We hope this work inspires further discussion on MDO wargaming solutions.

## ACKNOWLEDGEMENTS

The authors would like to thank Theo van der Zon and Thomas Bellucci for their aid in realizing the ideas we presented in the paper.

## REFERENCES

Appleget, J. (2021). An Introduction to Wargaming and Modeling and Simulation. In *Simulation and Wargaming* (pp. 1–22). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119604815.ch1

Bruvoll, S., Hannay, J. E., Svendsen, G. K., Asprusten, M. L., Magne, K., Kvernelv, V. B., Løvlid, R. A., & Hyndøy, J. I. (2022). Simulation-supported Wargaming for Analysis of Plans. *Scandinavian Journal of Military Studies*, *5*(1), 18.

Development, Concepts and Doctrine Centre. (2017). *Wargaming Handbook*. Ministry of Defence. https://www.gov.uk/government/publications/defence-wargaming-handbook

Doyle, D. S., Knoll, C. M., & Leard, D. R. (2025). Becoming Multidomain Practitioners: Tactical Training for Multidomain Operations at Echelon. *Military Review Online Exclusive*. https://www.armyupress.army.mil/Journals/Military-Review/Online-Exclusive/2025-OLE/Multidomain-Practitioners/

Evensen, P.-I., Hvinden, E. S., Holhjem, H. R., Tveit, D. M., & Eikås, K. D. R. (2024). *Requirements for Simulation of the Future Operating Environment and Multi-Domain Operations*. 2024 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC).

Flack, N., Lin, A., Peterson, G., & Reith, M. (2020). Battlespace Next(TM): Developing a Serious Game to Explore Multi-Domain Operations. *International Journal of Serious Games*, *7*(2), 49–70. https://doi.org/10.17083/ijsg.v7i2.349

Gatla, R. K., Gatla, A., Sridhar, P., Kumar, D. G., & Naga Malleswara Rao, D. S. (2024). *Advancements in Generative AI: Exploring Fundamentals and Evolution*. 1st International Conference on Electronics, Computing, Communication and Control Technology, ICECCC 2024. Scopus. https://doi.org/10.1109/ICECCC61767.2024.10594003

Hodický, J., Procházka, D., Baxa, F., Melichar, J., Krejčík, M., Křížek, P., Stodola, P., & Drozd, J. (2020). Computer Assisted Wargame for Military Capability-Based Planning. *Entropy*, *22*(8), 861. https://doi.org/10.3390/e22080861

Hu, Q. J., Bieker, J., Li, X., Jiang, N., Keigwin, B., Ranganath, G., Keutzer, K., & Upadhyay, S. K. (2024). *RouterBench: A Benchmark for Multi-LLM Routing System* (No. arXiv:2403.12031). arXiv. https://doi.org/10.48550/arXiv.2403.12031

Huckle, J., & Williams, S. (2025). Easy Problems that LLMs Get Wrong. In K. Arai (Ed.), *Advances in Information and Communication* (pp. 313–332). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-84457-7_19

Janes. (n.d.). *Our Data and Analysis*. Janes | Open Source Defence and Security Intelligence. Retrieved 22 May 2025, from https://www.janes.com/osint-solutions/what-we-do/open-source-intelligence-data-system

Lehtoaro, T. (2023). *Defining the Center of Gravity: A theoretical model for multi-domain operations* [fi=Diplomityö (YE)|sv=Licentiatavhandling|en=Licentiate thesis|, Finnish National Defence University]. https://www.doria.fi/handle/10024/188015

Marchetti, G. (2018). Consciousness: A unique way of processing information. *Cognitive Processing*, *19*(3), 435–464. https://doi.org/10.1007/s10339-018-0855-8

Marler, T. (2023). *Unlocking Training Technology for Multi-Domain Operations*. https://www.rand.org/pubs/commentary/2023/01/unlocking-training-technology-for-multi-domain-operations.html

Muurmans, P., Toubman, A., Bellucci, T., Bezemer, K., & Van der Zon, T. (2024, September 23). *A Bottom-Up Approach to the Simulation of Multi-Domain Operations*. NATO CA2X2 (Computer-Assisted Analysis, Exercises, Experimentation) Forum, Rome, Italy.

Nakamura, J., & Csikszentmihalyi, M. (2009). Flow Theory and Research. In S. J. Lopez & C. R. Snyder (Eds.), *The Oxford Handbook of Positive Psychology* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195187243.013.0018

NATO Allied Command Transformation. (2022, July 29). *Multi-Domain Operations: Enabling NATO to Out-pace and Out-think its Adversaries*. https://www.act.nato.int/article/multi-domain-operations-enabling-nato-to-out-pace-and-out-think-its-adversaries/

Schwartz, P. J., O'Neill, D. V., Bentz, M. E., Brown, A., Doyle, B. S., Liepa, O. C., Lawrence, R., & Hull, R. D. (2020). *AI-enabled wargaming in the military decision making process*. *11413*. Scopus. https://doi.org/10.1117/12.2560494

Scott, K. (2022). 'Out Beyond Jointery': Developing a Model for Gaming Multi-Domain Warfare. *International Conference on Cyber Warfare and Security*, *17*(1), Article 1. https://doi.org/10.34190/iccws.17.1.77

Weissenberger, B. (2024). Seeding Success: Generating Valid and Realistic PMESII Start Values for Serious Wargames and Simulators. *NATO Modelling & Simulation Centre of Excellence (MSCOE)*. https://www.mscoe.org/document/seeding-success-generating-valid-and-realistic-pmesii-start-values-for-serious-wargames-and-simulators-2/download/