ON THE DESIGN OF EDUCATIONAL COURSE OF ACTION WARGAMING

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ABSTRACT

The Joint Planning Process is a document that describes the guidelines to employ the Brazilian Armed Forces. The military can also apply these guidelines for educational purposes, to train their staff in times of peace. The Brazilian Ministry of Defense intends to simulate the employment of military forces to speed up the decision-making cycle and increase the chances of operational success. Consequently, actions would be better planned and risks would be better assessed. The Course of Action (COA) Wargaming simulates each friendly COA against the possible enemy COAs. However, the doctrinal process lacks information to describe how to conduct a COA Wargame. Therefore, doctrinal knowledge is limited to systematizing this analysis. COA Wargaming has been subjective and has relied on tacit knowledge. This work aims to propose a method to conduct the COA Wargaming, and a conceptual model to structure the COA Wargaming, enabling the further use of computer systems to support its conduction. Wargames' concepts inspire this game design. Wargames are defined as models or simulations of conflicts in a synthetic environment, involving opposing forces, in which players make decisions based on rules, procedures, and information. Improving COA Wargaming as an educational wargame tool would simulate military planning, support players to build effective strategies, support instructors to analyze players' decisions and umpire engagements, and build a technological framework to collect decision data for future applications in knowledge management and artificial intelligence.

Keywords: wargames, COA Wargaming, military planning, military training, serious games

INTRODUCTION

Nations employ their Military Power to resolve conflicts or wars, or even to manage crises without resulting in effective combat actions. In the international political and economic situation, crises can escalate quickly and, consequently, conflicts can be declared immediately. In times of peace, the armed forces must be prepared and trained for these purposes. Thus, the military plans its actions by building scenarios and anticipating undesirable situations to avoid surprises (Neves, 2008).

The Brazilian Ministry of Defense intends to train the military staff and simulate the employment of military forces to speed up the decision-making cycle and increase the chances of operational success. Consequently, actions would be better planned and risks would be better assessed. The Joint Planning Process (Brazil, 2020) provides guidelines to employ the Brazilian Armed Forces, describing activities to plan and execute military operations. This doctrinal process has a sequence of steps, where the commander and his General Staff analyze the problem in all dimensions and develop possible Courses of Action (COA) to fulfill the mission. The result of the process is the choice of the COA that the military will adopt in the operation. The military can also apply this process for educational purposes to train staff. The process recommends some methods such as COA Wargaming to analyze – and assess – the COAs. COA Wargaming can simulate military employment since this activity attempts to visualize the flow of the operation. Each friendly COA is then wargamed against the possible enemy COAs (United States, 2020b).

The doctrine indicates that COA Wargaming suggests some conclusions about the COAs: degree of efficiency to fulfill the mission, risks, advantages and disadvantages, probable losses, need to synchronize actions, and identification of decision points and alternative actions (Brazil, 2020). However, the Joint Planning Process lacks information to describe how to conduct the COA Wargaming and what factors should be analyzed to reach these conclusions. Therefore, doctrinal knowledge is limited to systematizing this analysis. COA Wargaming has been subjective and has relied on tacit knowledge.

This work aims to propose a method to conduct the COA Wargaming and a conceptual model to structure the COA Wargaming, enabling the further use of computer systems to support its conduction. Wargames' concepts would inspire the design of

this computer system. Perla (1990) defines a wargame as "a warfare model or simulation, not involving actual military forces, and in which the flow of events is affected by and in turn, affects decisions made during those events by players representing the opposing sides". Hence, the COA Wargaming will act as an educational tool to analyze military officers' decisions and strategies and foster ideas and insights.

Improving COA Wargaming as an educational wargame tool simulates military planning, supports players to build more effective strategies, supports instructors to analyze players' decisions and umpire engagements, and builds a technological framework to collect decision data for future applications in knowledge management and artificial intelligence.

BACKGROUND

The military has developed methods and techniques to practice its activities in times of peace (McHugh, 1966), aiming to be prepared for a possible situation of crisis, conflict, or war. Wargames are one of these techniques based on battle simulation. Wargames are representations of conflict or competition in a synthetic environment, in which people make decisions and respond to the consequences of those decisions" (United States, 2020b).

Wargames are usually conducted over a map. Counters represent military units that are arranged on the map. Analysts control movement and combat actions. Rules or umpires adjudicate (judge) engagement results (Turnitsa, 2016). Figure 1 shows military personnel participating in a joint command wargame at a Brazilian military school of general staff in October 2021.

Figure 1: Military participate in a wargame at a Brazilian military school of general staff

Wargames teach thorough active (Pavek & Starken, 2014) and experimental learning (Lacey, 2016). Military use wargames as a key element in the continuous professional development of its leaders (Caffrey Jr, 2019) to explore the constant evolution of military doctrine and operational concepts (Kainikara, 2003). The human-in-the-loop gameplay characterizes the wargames. The absence of the human as a decision-maker would not characterize wargames as games, but as a model or a simulation (Elg, 2017). The human dimension contributes to understanding the wargame as a combination of art and science. The creativity and unpredictability of human decisions reinforce operational art. In contrast, rules, models, and data portray the science around the game.

Wargames are powerful tools to explore problems where players must make decisions in challenging situations, generate possible solutions (Bestard, 2016), and appreciate the consequences of these decisions (Wong, 2016). The central dynamic in any wargame focuses on the flow of information and decisions between players (Perla & Markowitz, 2009). Perla (1990), Elg (2017), and Kainikara (2003), for instance, point out that analyzing players' decisions are more important than losing or winning. Wargames produce real value when it focuses on well-defined choices and connects players' decisions to their performance (Frost et al., 1997).

Some reasons justify the design of a wargame: examine the effectiveness of a certain concept or doctrine (Appleget et al., 2016), encourage socialization (Rubel, 2006) and debate (Work & Selva, 2015), investigate combat processes (Perla, 1990), develop better strategies, explore alternatives and improve perceptions about likely courses of action (Wilkes, 2001). These reasons denote that wargames could be used in a military planning process. The Joint Planning Process (Brazil, 2020) reinforces these reasons since points out that friendly COAs and enemy COAs should be confronted in a wargame. Military doctrines from United States (2020) and NATO (2019) call this activity COA Wargaming. Since their names are similar, COA Wargaming and wargames are misunderstood as being the same subject. However, wargames are a broader and more complex subject than COA Wargaming. We prefer to state that COA Wargaming can apply concepts from wargames.

COA Wargaming is a method for conducting the COAs' analysis during the military planning process. A COA is a potential way to accomplish the assigned mission (United States, 2020b). The staff may develop many COA during this cognitive process. A COA unfolds into phases that contain a sequence of actions and decision points. Figure 2 presents a COA graphically; rectangles represent actions and triangles represent decision points. In addition, the staff Intelligence cell (Red Team) develops enemy COAs, that is, the possible COAs that the enemy would be able to undertake to affect mission fulfillment.

COA Wargaming visualizes the flow of operations in time and space considering the capabilities and possible dispositions of
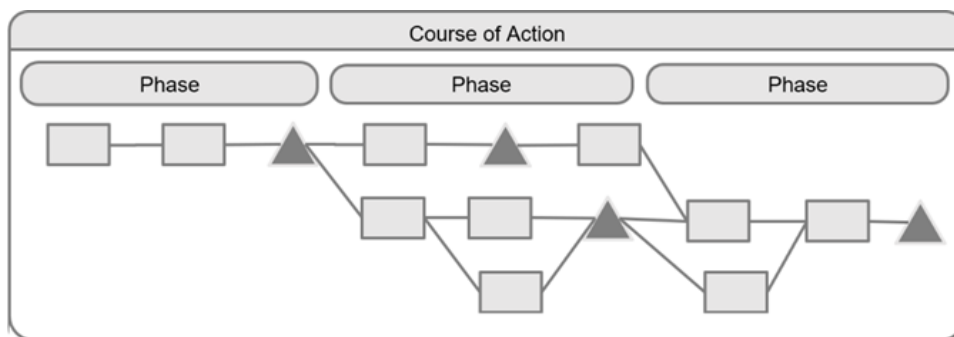

Figure 2: A graphical representation of a COA

friendly and enemy forces, the operational area, and other aspects of the operational environment (United States, 2020b). The main goal of COA Wargaming is to improve the COAs. Each friendly COA is wargamed against each enemy COA. In addition, each COA Wargaming allows us to: (1) identify difficulties, risks, and limitations in COAs; and (2) coordinate actions, effects, and decision points to achieve the desired end state (Eikmeier, 2015). In addition, the commander and staff can speculate how the situation might have unfolded if other decisions had been taken (United Kingdom, 2017). The simplest way to conduct the COA Wargaming is a manual approach. In this case, the military uses a map, a chart, or even a tabletop to manually reproduce COAs' actions and events. A more sophisticated approach uses complex computer-aided models and simulations to execute planned moves (United States, 2013).

Due to the complexity of the military terminology used in this work, we summarize in Table 1 some most often military terms using adapted descriptions gathered from official glossaries from NATO (2019a) and the U.S. Department of Defense (DoD) (United States, 2020a) (United States, 2020b).

TABLE 1:
Military Terms, adapted from NATO and U.S. DoD

Term	Description
Blue Team	Those forces used in a friendly role during NATO exercises (same as Blue Forces) (NATO, 2019a).
Course of Action (COA)	In the estimate process, an option that will accomplish or contribute to the accomplishment of a mission or task, and from which a detailed plan is developed (NATO, 2019a).
Enemy COA	COA taken by a declared, presumed, or recognized hostile nation, faction, or group (see definitions of COA and Enemy) (NATO, 2019a).
Engagement	An action taken against a hostile force with intent to deter, damage, or neutralize it (NATO, 2019a).
Exercise	A military maneuver or simulated wartime operation involving planning, preparation, and execution that is carried out for training and evaluation (United States, 2020a).
Friendly COA	COA taken by a declared, presumed, or recognized friendly nation, faction, or group (see definitions of COA and Friendly) (NATO, 2019a).
Joint Command	A unit, group of units, or organization that contains elements of at least two services, under the authority of a single individual (see definitions of Joint and Command) (NATO, 2019a).
Operation	A military action or the carrying out of a strategic, operational, tactical, service, training, or administrative military mission (United States, 2020a).
Red Team	An organizational element comprised of trained members that provide an independent capability to explore alternatives in plans and operations from the perspective of adversaries (United States, 2020a).
Staff	In a military organization, a group composed of military or civilian personnel that assists a commander (NATO, 2019a).
Task Force	A temporary grouping of units, under one commander, formed for carrying out a specific operation or mission (NATO, 2019a).
Wargame	Representation of conflict or competition in a synthetic environment, in which people make decisions and respond to the consequences of those decisions.(United States, 2020b).
White Cell	A small cell of arbitrators normally composed of senior individuals familiar with the plan to ensure the wargame does not get bogged down in unnecessary disagreement or arguing. The white cell will provide overall oversight to the wargame and any adjudication between participants (United States, 2020b).

RESEARCH PROBLEM

First, we formulated the research problem: the Joint Planning Process (Brazil, 2020) lacks information to describe how to conduct the COA Wargaming in COA analysis. We need to understand how the COA Wargaming should be conducted to analyze and improve COAs to simulate the employment of military forces.

The military planning process may be applied in different contexts, outside the military. Some governmental applications of such planning model may include Homeland Security, Policial Operations, and Preparedness and Response in Disasters. Besides, in the market, businesses use several methods to develop their market *strategies*, and military planning influenced their development (Keller, 2008). The reverse situation – business methods used in military planning – are also seen. For instance, the military planning process may include a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to improve COAs (NATO, 2019b).

We defined two research questions from the problem statement:

- RQ1: How do the general staff conduct COA Wargaming in a military planning process?
- RQ2: How should COA Wargaming be structured to enable the use of computer systems to aid in its conduct?

RELATED WORKS

This section presents related works to COA Wargaming. First, these works are listed in Table 2, then their contributions are discussed in subsequent paragraphs.

TABLE 2
COA Wargaming Related Works

Reference	Goals	Findings	Limitations
Lowis and Barlow (2003)	Describe a system that uses agent-based simulation to conduct the COA Wargaming.	The use of the new tool allowed the military to visualize the flow of action, increased their insight and understanding, and reduced the time taken to conduct the COA Wargaming.	Limited experiments, subjective evaluations of the system, few warfare scenarios.
Hofmann and Lehmann (2007)	Discuss the integration of Tactical and Operational (COA) Wargaming through simulation.	Objective evaluation of COAs is impractical due to their subjective interpretation and influence. Many parameters are not directly measurable due to missing information or the non-existence of quantifiable parameters.	Limited experiments.
LBS Consultancy (2011)	Spread COA Wargaming best practice.	Lacks a doctrine to fully explains COA Wargaming. So military misunderstood how to properly carry out this analysis.	Lacking supporting experiment.
Waldenström (2012)	Discusses and evaluates the use of simple simulators in training and education.	A low-fidelity simulator can be an effective tool. Fidelity is not the key issue, but rather how well the simulator is integrated into the learning context.	Uses a low-fidelity naval wargame.
Hernandez (2015)	Develop a framework that systematically investigates and executes wargame to derive new evaluations, establishing wargames as a sound research technique for complex issues.	The experiment highlighted factors that the staff should have considered in the wargame but was absent in the planning process.	Limited experiments.
Hanson (2016)	Explores the causes of wargaming failures and proposes suggestions for successful wargames.	COA Wargaming is a powerful technique for training and refining operational plans. But current doctrine lacks sufficient detail on how to design and conduct wargames, neglecting some needs of planning staff.	Lacking supporting experiment.
Guarda et al. (2017)	Establish the applicability of an open-source simulator as a support tool for planning naval operations thorough study of the relationship between planning, wargaming, and simulation.	The simulator is capable to generate a synthetic computing environment, representing adequately the dynamics that characterize naval operations. In COA wargaming, the simulator establishes a useful basis for the decision information.	Limited experiments.
Hanley Jr (2017)	Suggest Game Theory approaches for recurring operational wargaming.	Creating computer programs to represent COA Wargaming in strategic form is feasible.	Lacking supporting experiment.

McConnell et al. (2018)	Examine the effect of paper and pencil role-playing games on improving performance during the COA Wargaming.	Participants played *Kriegspiel* and demonstrated a statistically significant increased capability to see themselves in the context of their operational environment, addressing threats and opportunities, and integrating those discoveries across warfighting functions.	only considered the role-playing game *Kriegspiel*.
Ouriques et al. (2019)	Understand how the knowledge is codified and flows during the COA Wargaming.	Doctrine is insufficient to build a suitable conceptual model for COA Wargaming. The tacit knowledge retained in officers must be also identified.	Only analyzed the Brazilian Military Planning doctrine.

The LBS Consultancy (2011) gathers good practices for COA Wargaming and denoted this analysis is poorly understood among the military and often, for this reason, badly executed and then discredited or discarded. We agree with their statement and understand that a decade later this situation is still true. Hanson (2016) reinforces that US military doctrines lack sufficient guidelines to prepare and conduct COA Wargaming. Military planners and instructors often rely on wargaming techniques from tactical knowledge, experience, and non-doctrinal handbooks. Ouriques et al. (2019) applied knowledge management techniques to understand how to develop the friendly COAs and enemy COAs in the context of COA Wargaming, using the previous edition of the Join Planning Process (Brazil, 2020), which dates from 2011. The current edition of the Join Planning Process provides a few changes and slightly better explains the COA Wargaming.

McConnell et al. (2018) scrutinized the effect of simple paper and pencil role-playing games on improving performance during the wargaming step of a military decision-making process. Results showed that military students who played the wargame (test group) before the wargaming step improved capabilities to visualize the operational environment, and anticipate threats and opportunities more readily than student participants who only exploited the process instruments (control group).

Waldenström (2012) presented a wargame to analyze decisions at the higher command levels of naval warfare. Players face problems on squadron, flotilla, or fleet-level. The game comprises scenario design, planning, execution, and analysis. In the planning phase, the game allows elaborating friendly COAs and enemy COAs. The article omits (does not indicate) whether the game includes COA Wargaming in the planning. Nevertheless, the dynamics of the execution phase are similar to the steps of COA Wargaming.

Guarda et al. (2017) examined the feasibility of a synthetic computational environment for a strategic wargame in the Brazilian Navy. Wargame and simulation features have been combined into a simulator, which confronts friendly COA against enemy COA. Wargaming methods were essential tasks (critical events) and provided closed information to players. Wargame had worksheets to record tasks (actions) and decisions.

Waldenström (2012) and Guarda et al. (2017) employed the COA Wargaming for educational purposes. But Hofmann and Lehmann (2007) simulated the consequences of COA analytically considering stochastic processes that generate statistical parameters, such as expected value and variance. This approach requires data-rich systems. However, their results indicated that the COAs' assessment tends to be subjective and many parameters are difficult to quantify at the operational level.

Lowis and Barlow (2003) employed an agent-based simulation to improve the COA Wargaming. Their experiment compared the proposed solution with techniques of COA analysis. The results indicated a clear and significant gain in situation awareness and reduced the time to conduct the COA Wargaming.

Hanley Jr (2017) proposes to use Game Theory to describe COA Wargaming in an extensive tree form. The decisions and, consequently, the actions of opposing players represent the branches of the tree. Hence, players must know the opponent's possible actions. If the analysis focus on strategy and payoffs, a two-dimensional matrix can replace the extensive form. However, decision payoffs will be difficult to quantify. Hernandez (2015) also considered using Game Theory to improve the analysis of wargames but warned that limiting decisions to a finite number of choices would restrict the exploratory nature of wargames.

RESEARCH METHOD

The epistemological paradigm of Design Science (DS) was the foundation for this research. DS focuses on the process for building knowledge and produces results that are relevant to both the global practice and the research community (Johannesson & Perjons, 2014). DS comprises the study of the project to design a new artifact or improve an existing artifact to solve a problem or a class of problems (Dresch et al., 2015).

Design Science Research (DSR) was the strategy we used to plan, execute and monitor the research. DS suggests adopting DSR to operationalize the research when the goal is to develop an artifact. Based on the problem description, DSR guides the research to design and evaluate artifacts that make changes to a given system and transform situations to achieve improvements (Dresch et al., 2015). DRS steps include identifying the problem, defining requirements and design, developing, demonstrating, and evaluating the artifacts.

The data collection provided the requirements for the design of the artifacts. We used the mixed-method approach since a

single method was insufficient to answer the research question. Documents (Johannesson & Perjons, 2014) were our first data source. We searched for *explicit knowledge* contained in military doctrines of other countries and military organizations. All documents that we examined and cited in this work are unclassified. The other methods we used were observation and interviews (Johannesson & Perjons, 2014). We also searched for *tacit knowledge* from Brazilian military officers to understand how they conduct COA Wargamings, especially in their educational activities.

Next, we gathered and analyzed the data to design the artifacts. We applied the Grounded Theory (Pandit, 1996) as a method for qualitative data analysis. We designed a method to conduct the COA Wargaming and a conceptual model, which depict the COA Wargaming structure. Data analysis allowed us to identify the concepts, categories, and propositions (Pandit, 1996) about COA Wargaming. Proposed artifacts suggest hypotheses about propositions across categories. We reached our goals for each artifact after a few cycles of data collection and analysis. In each cycle, the hypotheses proposed in the artifacts were evaluated by experts in military planning and wargaming.

The following subsections describe the activities that we performed during this work, which included reviewing military documents, directly observing COA Wargamings in two training exercises at a military school of general staff, and interviewing military officers who participated in these exercises. These analyzes focused on the methods and dynamics for conducting COA Wargaming.

Military Doctrines

Our research to grasp COA Wargaming began scrutinizing the doctrines from United States armed forces that Hanson, (2016) had examined. Although Hanson pointed out the limitations of these doctrines to guide how to conduct the COA Wargaming, we found that they have more information than the Brazilian doctrine (Brazil, 2020). Instead of searching for the doctrines from other countries, we first analyzed the doctrine from NATO (2019), which underlines that allied countries such as the United Kingdom, Germany, and France assumed this same process. In addition, we also analyzed the military planning process from Australia, (2019), which is not a member of NATO. Table 3 shows all doctrines that we reviewed.

TABLE 3
Military Planning Doctrines

Title	Source
Air Force Doctrine Publication 3-0 - Operations and Planning	United States
Command and Control of Joint Air Operations (JP 3-30)	United States
Joint Planning (JP 5-0)	United States
Marine Corps Planning Process (MCWP 5-10)	United States
Navy Planning Process (NWP 5-1)	United States
Allied Joint Doctrine for the Planning Operations (AJP-05)	NATO
Joint Military Appreciation Process (ADFP 5.0.1)	Australia

All doctrines analyzed COA Wargaming from a systemic perspective. Doctrines describe COA Wargaming as a process that has inputs, steps (sub-processes), and outputs. However, each armed force has its peculiarities to conduct the COA Wargaming. Each one defines some methods according to the needs of the operating environment in which it operates. All doctrines indicate that the friendly COAs and the enemy COAs elaborated in the previous planning steps are the main inputs to COA Wargaming. Nevertheless, military planners only use the most likely and most dangerous enemy COAs due to time constraints often faced in planning. Other possible inputs would be the commander's intent (United States, 2016), evaluation criteria, a preliminary risk analysis (United States, 2020b), a map of the operational area, and assumptions made in planning (United States, 2014).

The COA Wargaming activity is performed in the COA analysis. The commander and staff analyze each COA separately according to the commander's guidance (United States, 2013) to identify difficulties, coordination problems, and the probable consequences of the planned actions (United States, 2014). Joint Planning (JP 5-0) divides COA Wargaming into four steps: prepare for the wargame, conduct the wargame, evaluate the results, and prepare products (United States, 2020b). But other military doctrines define two steps in wargaming: prepare and conduct. We will use the Joint Planning steps (Figure 3) notation to better explain the COA Wargaming process.
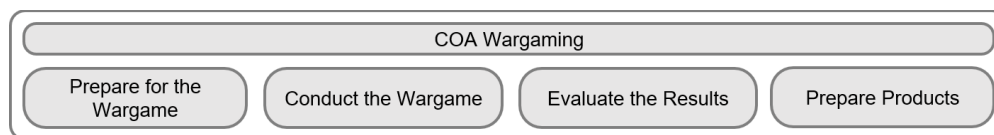

Figure 3: COA Wargaming steps from Joint Planning (JP 5-0)

The first step – named *Prepare for the Wargame* – prepares the staff for the wargame conduction. The instructors determine

participants and staff organization (Australia, 2019). The commander and staff define the scope, the operational environment, and the method for conducting COA Wargaming. Each method stimulates a specific dimension of military planning: force, time, or space.

The Joint Planning (United States, 2020b) defines three COA Wargaming conduction methods (Deliberate Timeline Analysis, Phasing, and Critical Events) that are performed manually. A computer-assisted COA Wargaming can also use these methods, as long as the staff develops the COAs properly. The Deliberate Timeline Analysis method considers sequential actions using discrete timeframes, usually day-by-day. The Phasing method analyses the most significant actions for each COA phase. The Critical Events method focuses on force comparison and the critical events to conduct the COA, demanding a meticulous analysis. The Deliberate Timeline Analysis and Phasing methods are focused on the time dimension of military planning. The Critical Events method relies on the force dimension. Thus, the JP 5-0 points out that the force must synchronize actions in time; on the other hand, it disregards the characteristics of the operational area.

The Commander and Staff Organization and Operations (FM6-0) (United States, 2014) recommends methods that define areas of interest in the operating environment, where enemy forces can affect the outcome of the operation. The methods divide the operational area into belts of the same width, avenues in-depth at a time, or boxes of critical areas. Planners can combine the methods or use them apart. The Navy Planning Process (NWP 5-1) (United States, 2013) and the Marine Corps Planning Process (MCWP 5-10) (United States, 2016) both have similar planning processes that define four methods: belts, avenues in-depth, boxes and essential tasks (critical events). On the other hand, the US Air Force doctrine (United States, 2019) lacks details on the steps and methods of COA Wargaming. The Allied Joint Doctrine for the Planning Operations (AJP-05) (NATO, 2019b) also defines that the COA Wargaming may be conducted by phases, decisive conditions (critical activities), and segments of the operational area (specific areas). The Joint Military Appreciation Process (ADFP 5.0.1) (Australia, 2019) suggests the following methods for conducting COA Wargaming: sequence of actions (time-event), critical event (time-box), avenue in-depth, and belt. This wargame consists of both parties acting simultaneously, followed by a results review. Therefore, both plans are analyzed concurrently in time and space, differing from other doctrines that use alternating moves to expose each party's actions. The Joint Planning Process (Brazil, 2020) recommends the following methods: sequence of action day by day, phasing, geographic areas, or critical events. But staff can choose other methods. The doctrine does not guide or restrict how to divide the operational area. Furthermore, we assume that the staff has insufficient time to analyze the friendly and enemy actions on a daily basis in military planning.

Table 4 lists the methods that military doctrines suggest for conducting the COA Wargaming for each dimension of military planning.

TABLE 4
COA Wargaming methods

Methods	Dimension
sequential actions, phasing	time
critical events, decisive points	force
box, belt, avenue-in-depth	space

The core of the COA Wargaming occurs during the *Conduct the Wargame* step – using an analogy with games, the conduction phase is the moment in which the players *actually* play the game. During this step, the commander and staff decide when and where they employ the friendly and enemy capabilities, manage risks and analyze COAs considering their feasibility and acceptability, and their logistical sustainment. The chief of staff adjudicates players' decisions, considering the doctrine and their own experience. First, the commander explains the scenario that originated the situation to the staff. Next, the operations officer exposes the COA and the intelligence officer exposes the enemy COA that will oppose the friendly COA. Then, the COA Wargaming begins and will be performed in alternating turns between the COAs.

A COA Wargaming turn expresses the move interactions that staff undertakes in each area of interest or COA element –phases or critical event. Each turn usually consists of three moves: action, reaction, and counteraction. But the chief of staff can allow further moves in each turn as deemed necessary to determine the effectiveness of each COA. Actions are those events initiated by either the side with the initiative. Reactions are the opposing side's response to actions. Counteractions are the first side's responses to reactions (United States, 2013). The chief of staff also sets the side with the initiative for each turn. The friendly force usually takes the initiative of actions and, in the same turn, will take a counteraction. Turns continue until the chief of staff ensures that actions are effective against the enemy force or the COA reaches an evaluation criterion.

These turn-based interactions are the simplest and most common approach in wargame design. In one move, the active side exposes its actions while the opposite side stands and watches. The alternate moves also reflect the nature of real military operations: successive offensive and counteroffensive actions by each side in turn are more common than simultaneous attacks (Sabin, 2012).

Figure 4 shows a framework that demonstrates the conduct of COA Wargaming. First, the staff presents the scenario, the actual context, and both COAs (friendly and enemy). Then, the sequence of turns begins. In this example, each turn comprises an action, a reaction, and a counteraction; the friendly force (Blue) has the initiative of action, therefore, undertakes an action and a counteraction. The enemy force (Red) only undertakes a reaction.
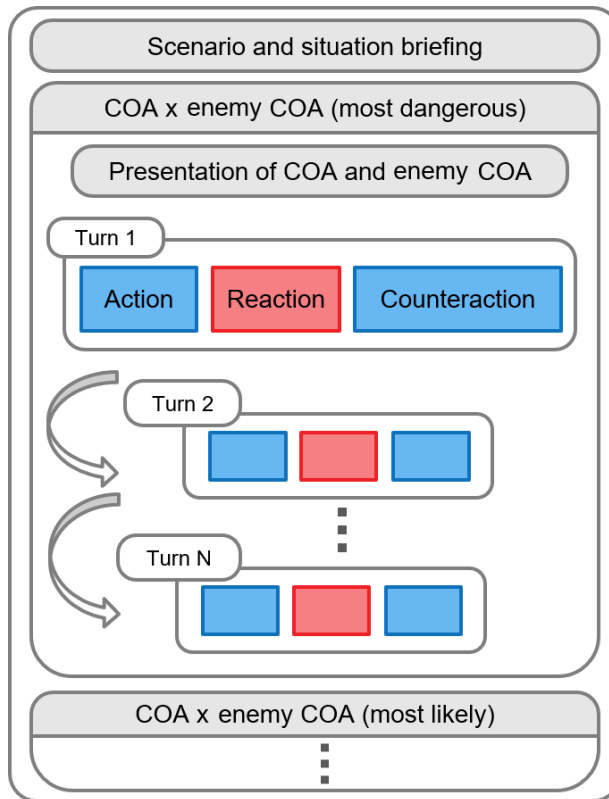
Figure 4: COA Wargaming move interaction, adapted from (NATO, 2019b)

In the *Evaluation of Results* step, the commander and staff improve friendly COAs. In the next step in the planning process, they will compare the advantages and disadvantages of COAs. Therefore, the main result in each COA Wargaming is an improved COA based on staff assessments. The doctrines also point out other outputs that contribute to improving COAs: defining strengths and weaknesses (advantages and disadvantages); identifying variants, decision points, critical events, and actions; and managing risks. Other possible outputs include candidate targets, alternative actions, and support actions (Brazil, 2020); instructors' conclusions (NATO, 2019b)**,** and updated assumptions (United States, 2014). Time permitting, the staff delivers a briefing analysis to ensure that the entire staff understands the relevant points and the results of the wargame (United States, 2014).

Finally*,* the *Prepare Products* step comprises the creation of new artifacts that will also support the commander in deciding
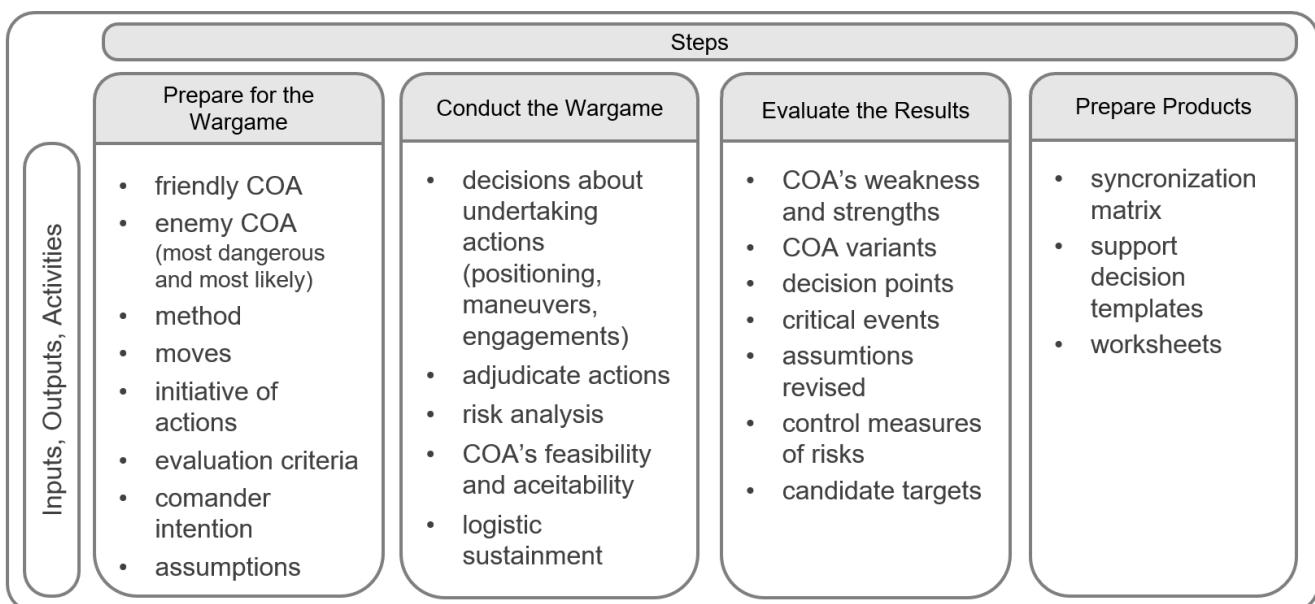

Figure 5: COA Wargaming conceptual framework

which COA to adopt at the end of the planning process. The products commonly generated from the results of COA Wargaming are a synchronization matrix, decision support models, spreadsheets, and other worksheets (United States, 2020b). The improved COA is converted into a synchronization matrix, where actions are synchronized in time and space to achieve objectives and the desired end state. Figure 5 summarizes the products that staff construct and enhance during the COA Wargaming, and also indicates some activities that staff undertakes in each step.

Observation and Interviews

Although foreign doctrines have more information about the COA Wargaming and have made the methods better clear to us, we still needed to understand how Brazilian Armed Forces conduct this activity, especially to consider the particularities of the Joint Planning Process (Brazil, 2020). Hence, we gathered information through direct observation (Johannesson & Perjons, 2014) of the COA Wargaming carried out in two training exercises at a military school of general staff. We also interviewed military officers who participated in these exercises.

In both exercises, the COA Wargaming had an educational purpose and the staff conducted the activities in a seminar format. COA analyzes are carried out in a plenary. Thus, these training exercises aimed to analyze the staff decisions and stimulate initiative, creativity, ideas, arguments, and discussions among military officers.

The first COA Wargaming was a Joint Training Exercise among Army, Navy, and Air Force. The instructors divide military officers into groups, each one composing a Joint Command. This configuration allows to produce more competing strategies, thus, develop more friendly COAs. Each Joint Command has a commander and his (general) staff. Each staff is further divided into the chief of staff and their sections, which represent each activity performed in a military operation: Personnel, Intelligence, Operations, Logistics, Planning, Command and Control, and so on (Brazil, 2020). The instructors use their criteria to define who will take each role in the exercise – a subject that is beyond the scope of this work. The military schools value merit, choosing the best performing officers to the key roles: thus, the officers best ranked in the course assume the roles of commanders, then, the chiefs of staff. The sections officers are also chosen based on the rank in the course, however, the instructors also consider their background and expertise. Each officer informs at the beginning of the course their expertise and in which section they prefer to work.

The COA Wargaming goal is to *improve* the friendly COA. The instructors highlighted this goal to the staff. Therefore, the COA Wargaming includes the identification of COA's strengths, weaknesses, variants, risks, and other improvements. In each Joint Command, the officers had collaborated to develop their friendly COAs. However, intelligence officers had focused in understand the enemy to develop the enemy COAs. Both friendly and enemy COAs were described in terms of phases, decision points, and actions. Staff could develop many suitable COAs to accomplish the mission. Nevertheless, due to the short timeframe to perform the exercise, each Joint Command selected two COAs and two enemy COAs to be wargamed. Staff usually selects the most likely and most dangerous enemy COAs. This short timeframe can put pressure on players to make decisions (LBS Consultancy, 2011).

We watched the conduct of COA Wargaming in four Joint Commands. We simply called them JC1, JC2, JC3, and JC4. Each one was placed in separate classrooms. Each staff freely decided the conduction method, the number of movements of each turn, the side that initiates the actions, and the evaluation criteria. Although Joint Planning Process (Brazil, 2020) recommends that each turn has three moves – action, reaction, and counteraction – and the friendly force initiates the actions.

An instructor explained to us that if the staff has little or no experience in operation planning, instructors suggest they choose three moves and set the blue team to initiate the actions. On the other hand, if the staff are more experienced, the friendly COA is defensive, or the timeframe allocated to COA Wargaming is restricted, instructors suggest them to choose two moves and set the red team to initiate actions. Thus, in these cases, the staff will always meet one purpose of the COA Wargaming dynamic: offering the last word to the Blue team.

JC1 chose to conduct the COA Wargaming on the decision points. Even though Brazilian doctrine does not cite this method, instructors encourage staff to choose it. In addition, JC1 chose to undertake two moves – action and reaction – each turn, and the enemy (Red Team) initiated the actions. A map on the wall presented the operational area and sticky paper miniatures represented their units. In each turn, first, an intelligence officer selected and positioned enemy units on the map, and exposed their action; then, an operations officer selected and positioned friendly units, and exposed their reactions.

JC2 also chose to conduct the COA Wargaming on the decision points. However, they chose to undertake three moves for every turn and the friendly force (Blue Team) initiated the actions. JC2 created a slideshow in Microsoft PowerPoint to support the conduct of COA Wargaming. Each slide corresponded to a turn and had a map of the operational area and small images representing friendly and enemy units. The slideshow was projected on the classroom wall. An operations officer and an intelligence officer selected their units, dragged them over the map, and exposed their actions.

JC3 chose the phasing method and defined three moves for every turn, but the chief of staff could allow additional moves to assess COA effectiveness. In addition, the chief of staff decided which team would initiate the actions in each turn. JC4 chose the phasing method as well, defined three moves for every turn, and the blue team initiates the actions.

A map on the table showed the operational areas in JC3 and JC4. But the map in JC4 was also projected on the wall to make the staff's view easier. Counters represented friendly and enemy units. An operations officer and an intelligence officer placed their units over the map and exposed their actions.

In all Joint Commands, both friendly (Blue) and enemy (Red) forces actions considered time and distance factors, which are physical and logistical models that evaluate the COA feasibility (Brazil, 2020). At the end of each turn, the staff takes notes and makes conclusions to improve the COA. Therefore, staff can observe their planned actions and assess the risks to synchronize actions; anticipate, postpone, include or exclude a decisive point; change the actions or positions of friendly units, or even refine or discard the COA.

The second COA Wargaming was a Navy exercise with the educational goal of training officers to control a planned naval operation. The control activities include maneuvering naval units, achieving the planned objectives, and withdrawing from the operational area. The instructors divided officers into Task Forces, which also follows a general staff structure. This exercise occurred during a short training course; therefore, the instructors prioritize the officers' expertise over in-course ranking when defining their roles in the Task Forces.

We observed the COA Wargaming in two Task Forces, which were conducted through a videoconference in two virtual rooms. We called the Task Forces TF1 and TF2. A member of staff shared a slideshow presentation in Microsoft PowerPoint in each room. Both staffs conducted the wargames using the same dynamics of the JC2 in the joint training exercise.

TF1 and TF2 chose to conduct the COA Wargaming on the decision points and the friendly force initiated the actions in each turn. But TF1 chose two moves in each turn and TF2 chose three moves. Figure 6 shows a slide that we got from the TF2 presentation. This slide displays the arrangement of friendly (Blue) and enemy (Red) units in the operating area. The Blue units intend to surround and intercept the Red units.

Instructors criticized TF1's decisions to prepare the wargame because that dynamic offered the last move in the turn to the enemy force. Thus, that dynamic would compromise the educational purposes of the COA Wargaming: analyzing the friendly COAs, the actions of the blue team, and the commander's decisions.
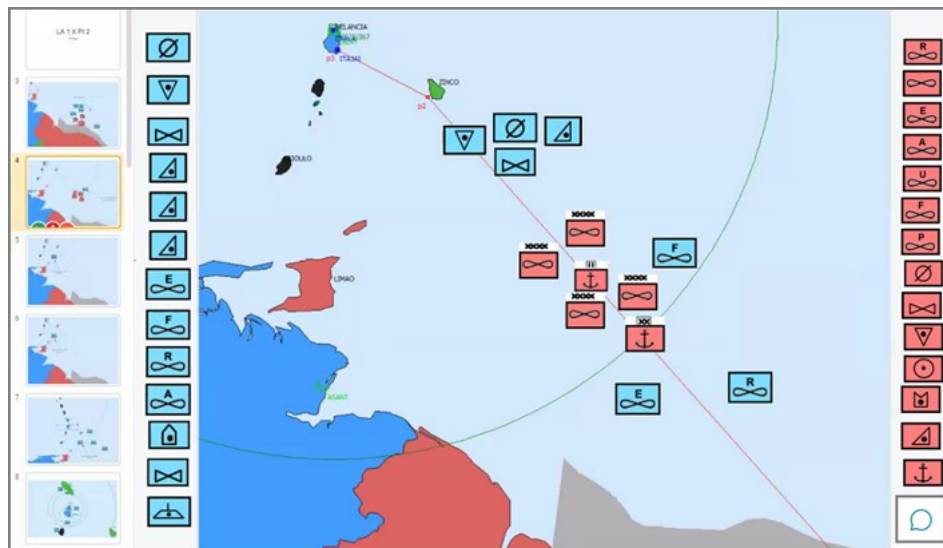

Figure 6: Snapshot of a COA Wargaming move in a Navy training exercise

Table 5 summarizes the different dynamics of the COA Wargaming that we watched in the four Joint Commands and the two Task Forces during the two training exercises.

TABLE 5
COA Wargamings in the training exercises

Staff Structure	Method	Moves	Initiative
JC1	decision points	Action - Reaction	Red
JC2	decision points	Action – Reaction – Counteraction	Blue
JC3	phasing	Action – Reaction – Counteraction – …	Red or Blue
JC4	phasing	Action – Reaction – Counteraction	Blue
TF1	decision points	Action – Reaction	Blue
TF2	decision points	Action – Reaction – Counteraction	Blue

RESULTS

The results of this work answer the two research questions that aim to acquire and produce knowledge to better conduct the COA Wargaming in the military planning process. We designed two artifacts - a method and a conceptual model - that followed the guidelines of Design Science (DS). The method describes the steps and activities to conduct the COA Wargaming, as well as its inputs and outputs. The conceptual model structures the COA Wargaming to enable a computer system to support its conduct. The artifacts fulfilled the goals of this work after a few cycles of data collection, data analysis, and evaluations by experts in military planning and wargames. The following subsections explain the design of each artifact.

COA Wargaming Method

We modeled the COA Wargaming process using the Business Process Model and Notation (BMPN) (OMG, 2013). First, we split the main process into the same four steps described in Joint Planning (United States, 2020b): Prepare for the Wargame, Conduct the Wargame, Evaluate the Results and Prepare Products. Figure 7 shows the main process, its sub-processes, and some inputs and outputs of the sub-processes. Next, we break the sub-processes down into activities to deepen the understanding.
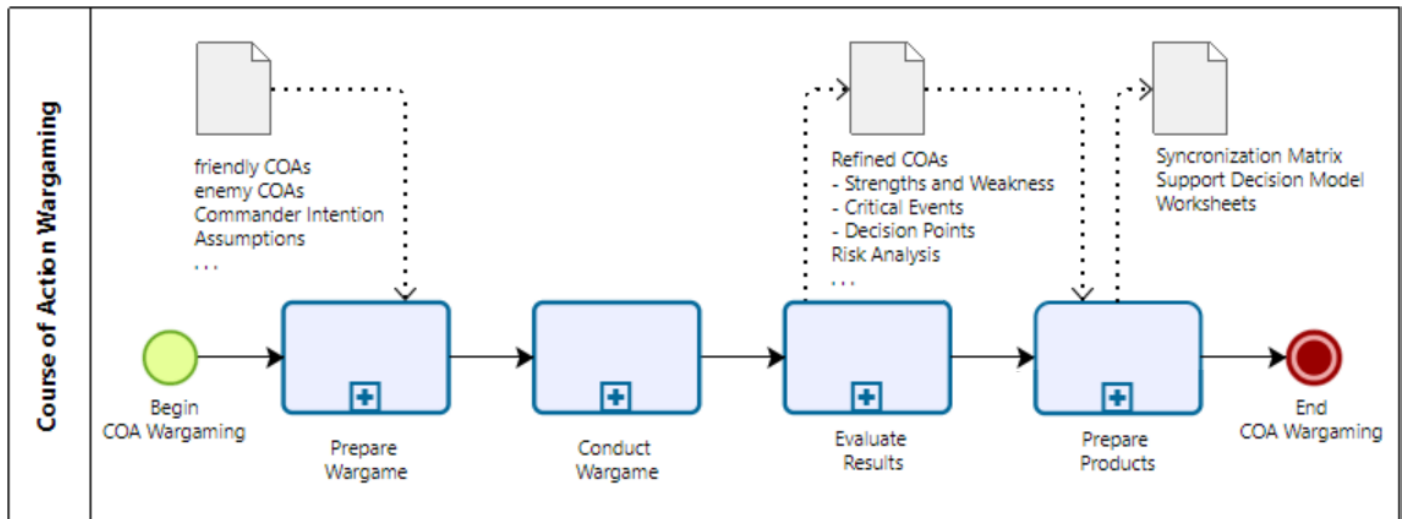

Figure 7: COA Wargaming process

The sub-process *Prepare Wargame* that represents the first step begins with instructors (white cell) defining the participants and their roles on the staff. Next, the sub-process details the main activities that staff members perform to provide the inputs to conduct the wargame. The instructors also set the date and time to start COA Wargaming (United States, 2016). The commander or the chief of staff defines the method to conduct wargame (phasing, critical events, sequence of actions, belts, avenue in-depth or boxes), selects the technique to record and display results, defines the evaluation criteria to reduce the subjectivity of the assessments (United States, 2020b), and list assumptions on the current situation or a presupposition on the future course of events (United States, 2014). The operations officers (Blue Cell) define the friendly COAs, which include their critical events and decision points, and list the units that can be committed to the operation (United States, 2013). At an earlier stage in the military planning process, a capabilities analysis selected the units available to carry out the mission. Finally, the intelligence officers (Red Cell) define the enemy COAs to be wargamed and list the enemy units. They usually select both the most dangerous and the most likely enemy COAs (United States, 2020b). Figure 8 details this sub-process.

The sub-process *Conduct Wargame* begins on the date and time the instructors set in the previous sub-process. The commander and staff collaborate to conduct the wargame. First, they announce and describe the friendly COA that will be wargamed against an enemy COA. Next, they announce and describe the enemy COA as well. Then the opposing sides – Blue Team and Red Team – fall into turn-based move interactions. A turn is associated with the conduction method. It can correspond to an area of interest or an element of the COA – phases or critical events. For instance, if the COA has four phases, the wargame will perform four turns. Turns continue until staff examines all COA's elements or all areas of interest, or reaches one or more evaluation criteria.

During these interactions, the staff continually evaluates the COA's feasibility and assesses its risks. At any time, the staff can decide to revise the COA; they can also reject the COA if it becomes unfeasible, then the wargame will be suspended.

After completing a wargame, the staff will select another friendly COA or another enemy COA to start a new wargame. This sub-process repeats as long as there is a friendly COA to be wargamed against an enemy COA. Figure 9 shows this whole sub-process.

Move interactions can be further analyzed as a sub-process as well. First, the chief of staff must define which side – Blue or
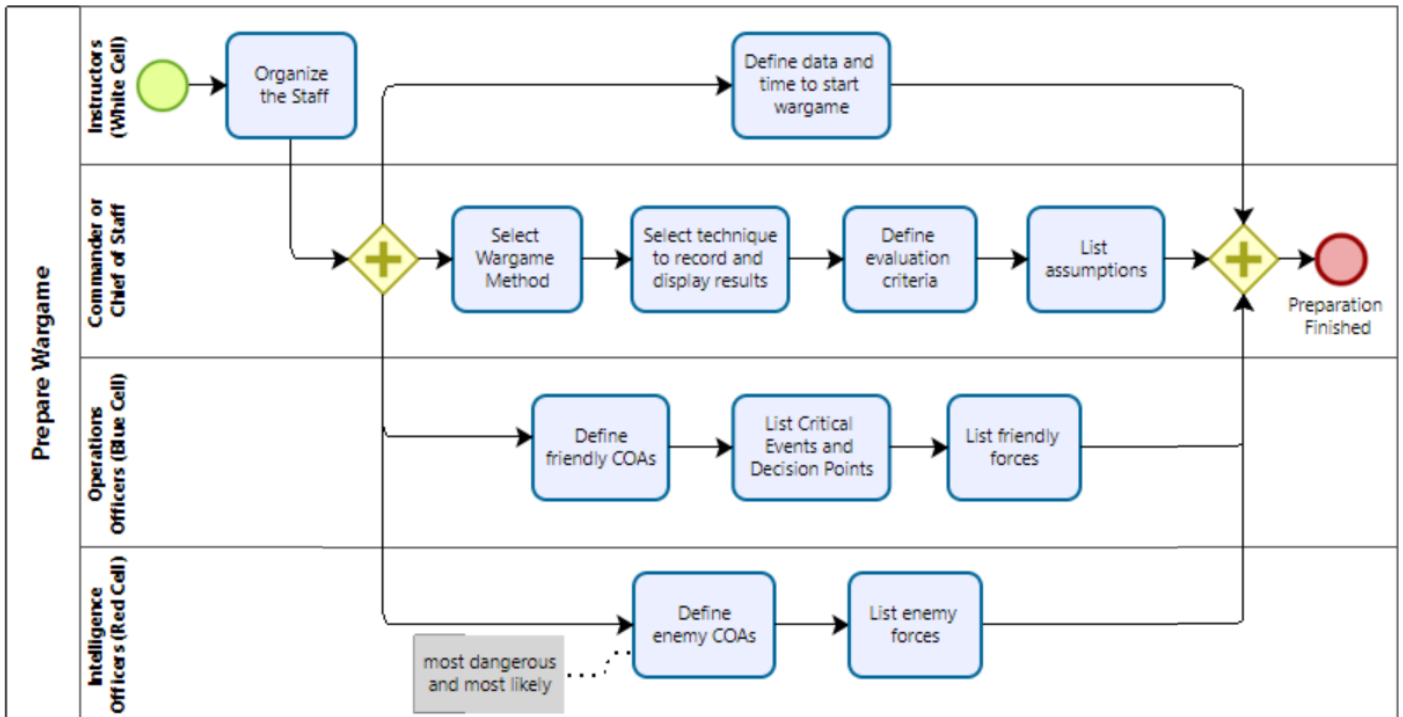
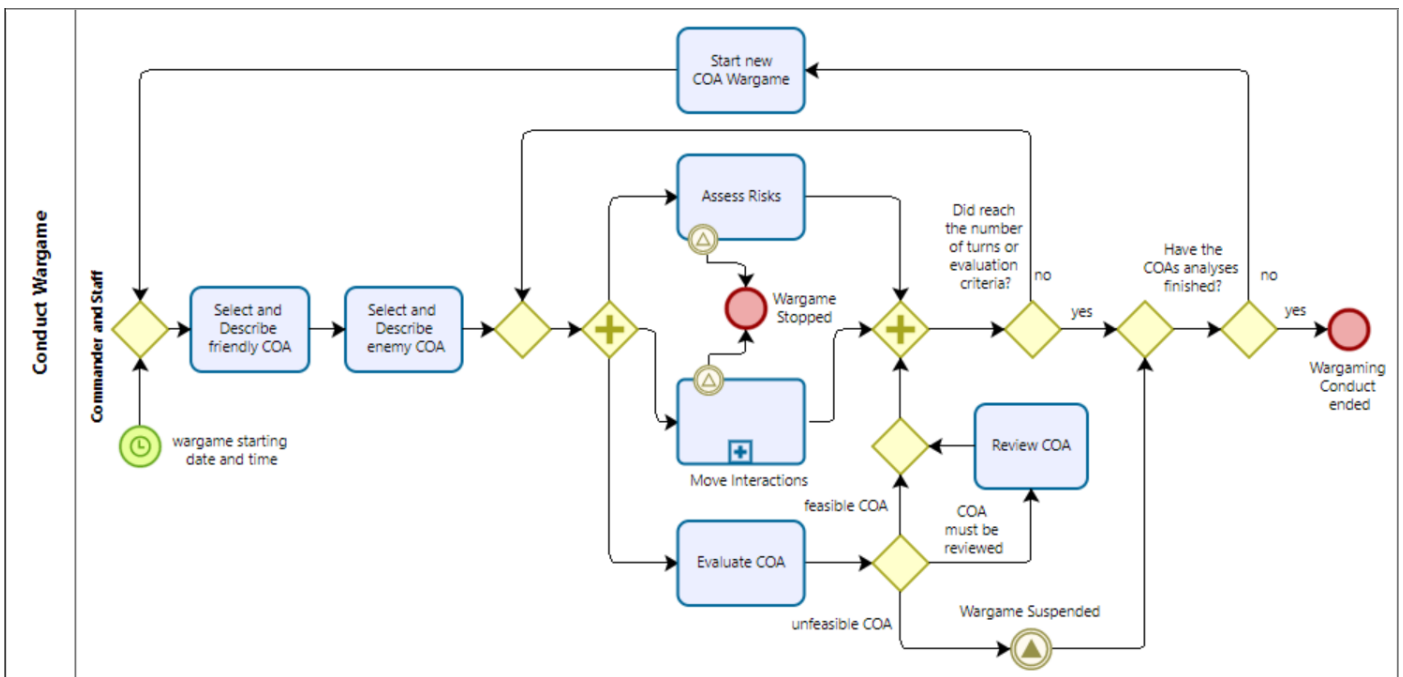**Figure 8: Prepare for the Wargame sub-process**

Figure 9: Conduct Wargame sub-process

Red – has the initiative to take action in all turns. But the chief of staff can define which side initiates the actions in each turn. The chosen side starts the move interactions, taking the first action. The opposite side reacts and then the chosen side counteracts. The move interaction usually comprises three moves. But the chief of staff can allow a further move to evaluate the COA's effectiveness.

An officer is responsible to record actions, conclusions, and results. The chief of staff usually appoints a planning officer to carry out this task. In addition, during the interactions, the chief of staff coordinates actions of both sides, and the commander adjudicates the (combat) actions between the opposing sides. The instructors analyze the decisions of both sides, but mostly from the

friendly side (Blue Team) since their interest is in assessing the COA. They can also promptly interrupt the game at any time to criticize or praise the staff's decisions, or point out flaws in the wargame's conduct if the staff is not following doctrinal guidelines.

Figure 10 shows the *Move Interactions* sub-process. The core of this sub-process is the move interactions exposed by operations officers (Blue Team) and intelligence officers (Red Team).
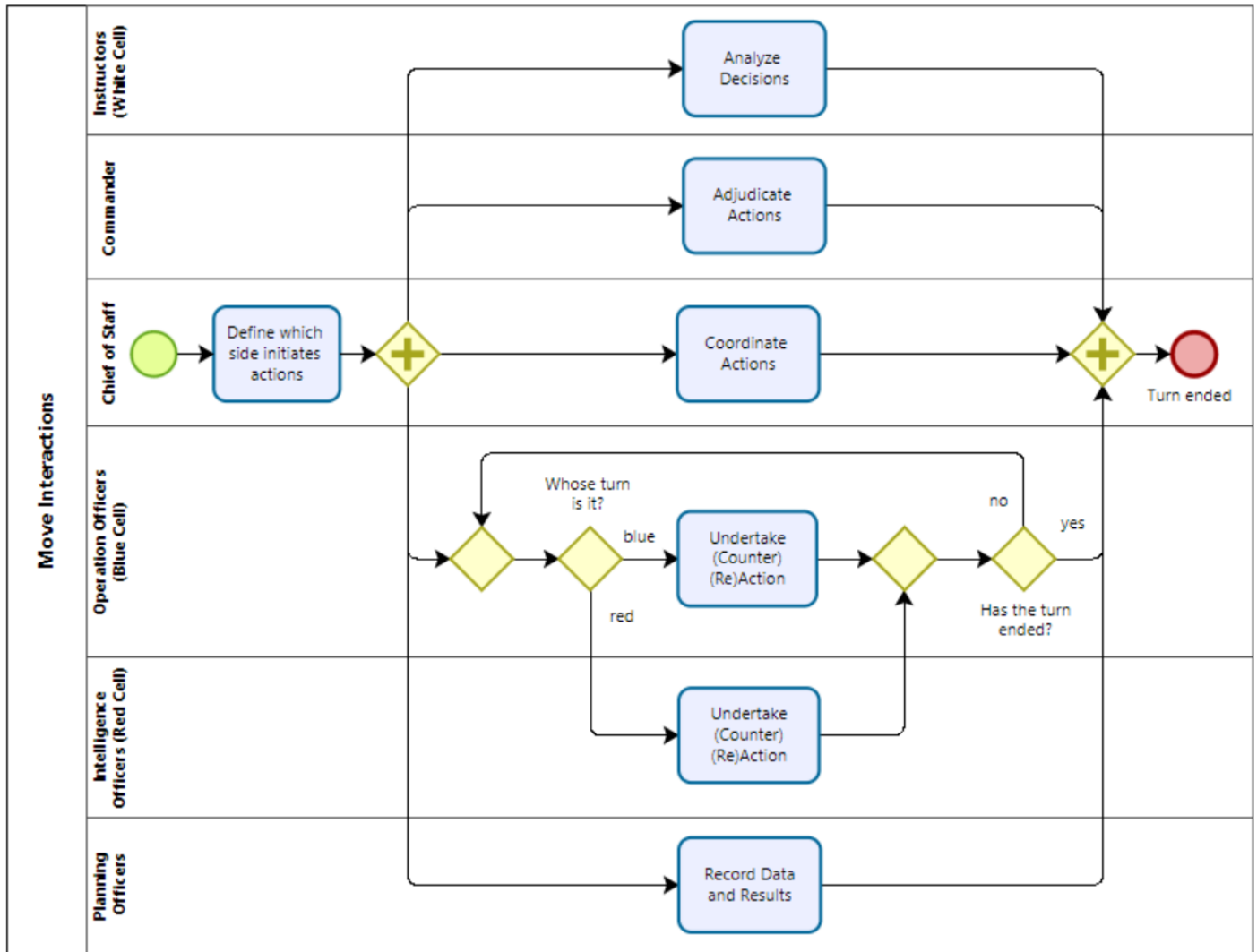

Figure 10: Move Interactions sub-process

In sub-process *Evaluate Results,* the Commander and Staff identify the wargame's conclusions – such as phases, decision points, actions, critical events, variants, and risk analysis – to refine all wargamed COAs. Finally, they conduct a briefing analysis to ensure that they recorded all relevant data and that the entire staff understood the results of the wargame (United States, 2014). Figure 11 shows this sub-process.

In the last sub-process *Prepare Products,* staff build products the staff builds products for all COAs from the wargame results. The products include the synchronization matrix, support decision models, and worksheets. Figure 12 shows this sub-process.

COA Wargaming Conceptual Model

We designed the conceptual model using a class diagram from UML (OMG, 2017) to represent the proposed method to conduct COA Wargaming. The concepts and elements of wargames inspired us to build this model. We found some initiatives to define the main elements that a wargame design must consider.

Wade (2018) defined four critical elements that must be properly designed for the wargame to meet the sponsor's objectives: *player, scenario, ruleset,* and *adjudication method*. Perla (1990) had previously defined essential elements for wargame design: *player, scenario, objectives, rules, database, models,* and *analysis*. These seven elements guided the studies of Weuve et al.
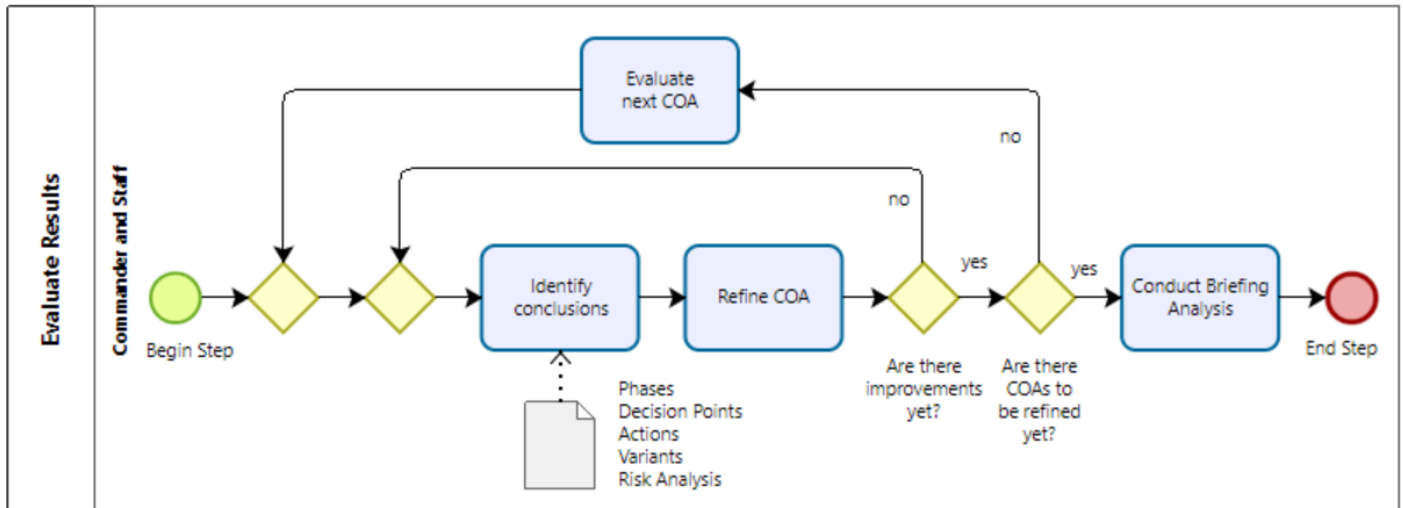
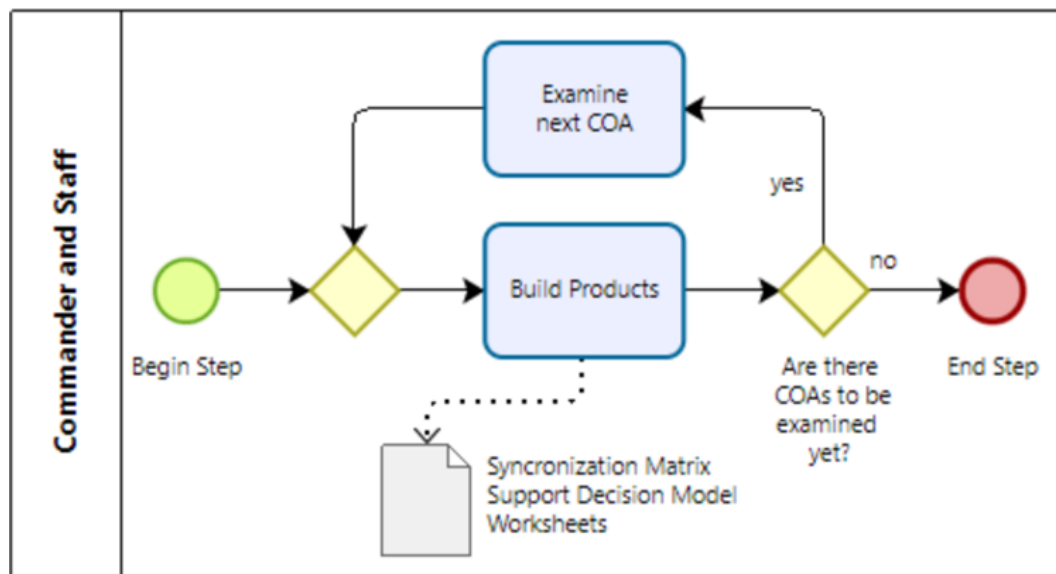**Figure 11: Evaluate the Results step**

Figure 12: Prepare Products sub-process

(2004), Mason (2012), and Pavek and Starken (2014). Weuve et. al proposed other wargame elements, such as the *infrastructure*, the *culture* and *environment* in which the game takes place, and the *audience*. They also defined a *participant* category, which includes *players*, *controllers,* and *observers*. Caffrey Jr, (2019) suggests that the principal elements of wargames are the participants: *Blue team* (friendly side), *Red team* (enemy side) and *White cell* (controllers and analysts).

The UK Ministry of Defense (2017) understands wargames as decision-making processes and points out that the core of wargames are the *players*, the *decisions* they make, the *narrative* they create, the *experiences* they share during the game, and the *lessons learned*. In addition, the UK Ministry of Defense describes that wargames contain the following elements: *objectives, scenario, setting, players* and their *decisions, simulation* (execution of wargame's models over time*), rules, procedures, adjudication process, data, supporting personnel*, *experts*, and *analysis*.

The model represents the COA Wargaming as an activity within the planning process of a military training exercise. Every exercise has a name and a mission statement and is directed toward attaining objectives (United States, 2020b), and takes place in a geographical area (or in a cyber domain). Instructors and students participate in these exercises. Instructors may divide students into (planning) groups. Hence, in the same exercise, the groups may analyze the scenario in different ways as well as may elaborate different strategies to face the situation (Wade, 2018). Each group constitutes a General Staff. Instructors also define the role of each staff member and set the start date-time of the wargame.

The main entries of COA Wargaming are the friendly COAs and enemy COAs. The staff is expected to develop both COA lists in the previous step of the planning process. Then, the staff defines a few COAs due to the limited time that instructors allocate to the wargame, commonly they define only two enemy COAs – the ones they consider most dangerous for their goals and the most

likely to happen. Each COA is wargamed against each enemy COA. A number identifies friendly COAs and enemy COAs. Friendly COAs contain phases, decision points, and actions. Enemy COAs describe possible actions that the enemy may undertake.

Before conducting a wargame, the commander and the chief of staff define the conduction method and suggest the number of moves for each turn. The method defines the number of turns since the turns can represent the COA's elements (phases, decision points, or actions) or segments of the operational area. Turns comprise the move interactions (action, reaction, counteraction, and so on) between friendly and enemy forces. In each turn, the chief of staff defines the side that will initiate the actions. Each force contains units whose actions represent these interactions. The wargame also portrays the deployment of units in the operational area, that is, the positions of the units are also recorded in each move. Wargame can represent different unit types directly, but this may increase counter requirements and rules complexity (Sabin, 2012).

This work focuses on the educational purpose of COA Wargaming. So, we are interested in analyzing the staff's decisions, which result in the conduction method, the number of moves in each turn, the side that has the initiative of actions, the evaluation criteria, and especially the actions that the units performed. At the end of each turn or after wargame conduct, the commander and their staff carry out an analysis to criticize staff's decisions and draw conclusions and lessons learned from the wargame.

Military doctrines suggest methods to record the COA Wargaming results. However, we have identified the possibility of developing a provenance model to further record not only the results but also most of the decisions made and aspects of the motivation from which those decisions were made. The provenance model could support reproducing the wargame for future analysis, enabling the didactic study of the decision-making process – a feature that has a special appeal in military schools.

Although we have designed the model for educational purposes, it also meets real planning. Thus, we just added an attribute in the Exercise class to indicate whether it is a training exercise or a real operation. Figure 13 shows the conceptual model.
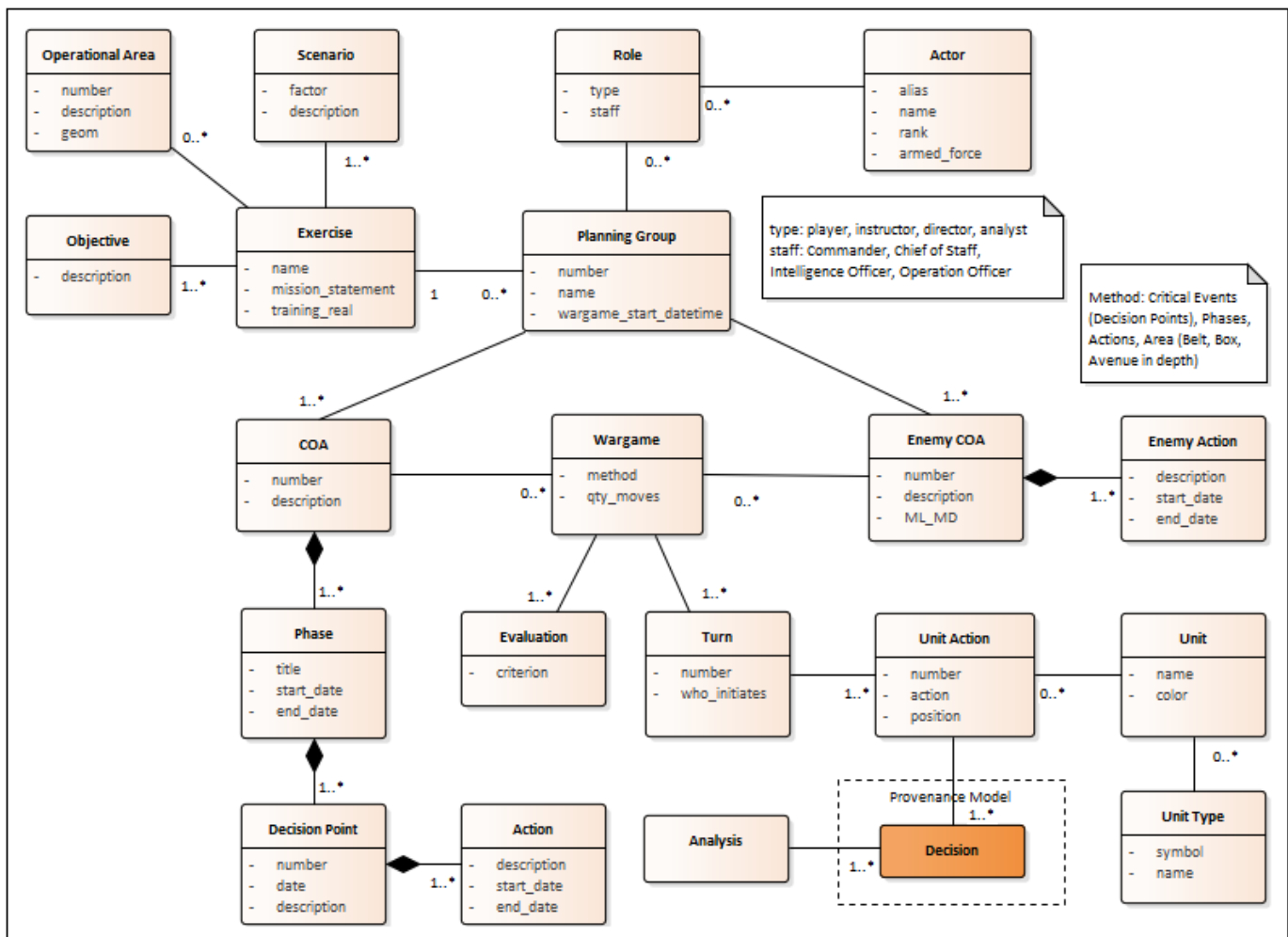

Figure 13: COA Wargaming Conceptual Model

The classes in the conceptual model reflect the main elements of the wargames suggested by Perla (1990) and the UK Ministry of Defense (2017). We can clearly identify the *scenario*, *objectives*, and *analysis* elements. The staff acts as *players*, but the

commander also acts as a controller since is responsible for adjudicating actions. The instructors act as *experts* or *analysts*. The *Blue team* develops friendly COAs and the *Red team* develops enemy COAs. The *rules* include the conduction method, turns, moves interactions, and the initiative of actions. *Procedures* include the wargame setup and the assignment of roles (Mason, 2012). The *database* stores all the military units, actions, decisions, evaluation criteria, and the geographical area (operational area) related to the exercise. For now, we will propose a provenance model for handling decisions, but we can use other *models* to support decision-making, such as kinematics, combat, or logistics to assess the COAs' feasibility.

The core elements from the UK Ministry of Defense (2017) emphasize the human aspect of war games and the values of decision-making and learning. The COA description, wargame turns, and move interactions build the *narrative*. The model highlights the players' *decisions* as well. Criticism of staff decisions contains *lessons learned*. So analysis translates tacit knowledge into explicit knowledge (externalization) (Nonaka et al., 1996). Lis (2014) reinforces that lesson-learning systems and after-action reviews (analyzes) are military approaches to externalize knowledge.

On the other hand, the model is unable to portray the *shared experiences* and the *adjudication model* because these elements are tacit knowledge of the staff. Members of staff share their previous experiences, that is, their share tacit knowledge (Dalkir, 2005). The adjudication method is free (Perla, 1990): staff's skills and experiences determine the results of engagements without requiring the use of any dataset or mathematical models.

We have reviewed the method and conceptual model with Navy planning instructors and wargame experts. After a few review cycles, we concluded that these artifacts answer the two research questions. Although qualified military personnel supported this analysis, it was partially subjective. A deeper analysis of these artifacts requires applying them to the design and development of a computational system to conduct the COA Wargaming.

DISCUSSION

We found in the two training exercises that staff and instructors could have handled decisions more relevantly during COA Wargaming. Although a staff member wrote a document to record the discussions, comments, and conclusions, certainly some knowledge was lost. Many decisions resulted in the actions that staff took on the units; or even included, changed, or excluded decision points, critical events, or variants.

Military doctrines even suggest methods for recording the wargaming such as a synchronization matrix (United States, 2014), a wargame matrix, narrative and sketch notes (Australia, 2019). The LBS Consultancy (2011) suggests recording decisions, conclusions, risks, and other considerations. But we assumed that decisions could be better handled in a structured way and properly stored using a provenance resource. Thus, stakeholders could better understand why the commander decided in a given situation, what criteria he used to make it, and what consequences resulted from the decision. In addition, COA Wargamings performed in these exercises and the commander's decisions could be consulted, analyzed, and discussed again for teaching purposes in the future. Finally, this knowledge could be properly shared in the military training environment.

We observed that both exercises occurred in military schools and, thus, the staff presented little to no experience in military planning. This is expected because such officers are just entering into the rank needed for military planning. However, joint operation exercises occur for several years further into the officers' careers. We foresee the opportunity to evaluate the tacit knowledge of experienced officers in joint operation exercises and compare it to the tacit knowledge of officers from military schools. Therefore, we can map which knowledge the military schools should reinforce to better train their officers.

Artificial Intelligence and other algorithms can be used in the context of analytic or educational COA Wargaming. Frequent uses include decision analysis and recommendation, generation of a realistic path for each type of unity, generation of dynamic and random events for stimulating officers' adaptation, development of realistic models for movement prediction for a given scenario, and creation of realistic models for engagement results based on the specs of the unities involved and physical characteristics of the operational area. Besides, the generated data from COA Wargaming should be recorded for further use in the development of machine learning approaches for simulating the behavior of the enemy COA. Coevolutionary deep learning algorithms may be used to perform as many COA Wargames as needed to seek the optimal COA. The development of intelligent agents to perform the COA Wargaming enables the agents to play both roles: friendly and enemy. In the friendly role, the wargame agent presents the default computer-based strategy, which should be at least matched by the officers. In the enemy role, the agent may present a formidable opposition at a level that the staff intelligence sector cannot produce due to the lack of manpower.

Another opportunity for including computer-aided algorithms in the COA Wargaming is between turns. We observed that during the COA Wargaming conduction, staff usually conduct the briefing analysis after every turn whether there is time available. Then, staff and instructors discuss the decisions taken and the entire COA Wargaming execution. Gathering and understanding such data may provide ways to extract tacit knowledge and further evaluate the success in wargaming. In addition, we could collect what decisions officer generally make in a COA Wargaming to develop decision data provenance – which can be further used to improve machine learning models and the quality of the automated decision-making process.

We observed two different exercises which employed COA Wargaming. In both exercises, they applied computer tools to aid the COA Wargaming – specifically the second Joint Command (JC2) in the joint exercise and the Task Forces of the Navy exercise. Although the results were similar when compared to the groups which developed the COA Wargaming without

computational aid, we identify the opportunity to improve the COA Wargaming through the use of a computer system tailored to the task, instead of using presentations as a digital sheet of paper. Such observations will be further analyzed and developed as a serious game (Michael & Chen, 2005) to conduct the COA Wargaming.

CONCLUSION

Since the Joint Planning Process (Brazil, 2020) lacks information about COA Wargaming, this work aimed to describe how to conduct this analysis to simulate the employment of military forces. We analyzed the COA Wargaming from the doctrines available around the world and we directly observed two different training exercises of the Brazilian military.

These analyses focused on the methods and dynamics for conducting COA Wargaming. Then, we summarize how the COA Wargaming is performed in practice, the differences between the doctrines they rely on, and the shortcuts taken by the staff when they have a few days to simulate an entire conflict. Therefore, we developed two artifacts: a method to conduct the COA Wargaming in a military planning process, which answered the first research question (RQ1); and a conceptual model to structure the COA Wargaming, which answered the second research question (RQ2). The COA Wargaming model enables the further development of computer systems to support its conduction and thus, aiding the employment of military forces in educational environments. There are computer systems for conducting wargames, but these technologies or solutions are proprietary. Countries do not publicly share their strategic knowledge.

Improving COA Wargaming as an educational wargame tool simulates military planning, supports players to build more effective strategies, supports instructors to analyze players' decisions and umpire engagements, and builds a technological framework to collect decision data for future applications in knowledge management and artificial intelligence. Wargames' concepts would inspire this game design.

As limitations in our work, we should to better understand how risk analysis is done in COA Wargaming. We also need to better understand in new field research which data we should extract from COA Wargamings to build a decision data provenance and which COA Wargaming evaluation criteria are used in practice. Further research is also needed in designing a serious game to conduct the COA Wargaming, based on actions that were collected in field research and aggregated into a Wargame MDA model (Ouriques et al., 2021). We also have some open questions, such as (1) "how COA Wargaming data provenance should be collected and reused?", and (2) "how and where can we introduce decision-making algorithms, such as decision trees (Clemen & Reilly, 2013), to aid the military to perform the COA Wargaming?".

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